ILLUMINATING ENGINEERING

MARCH 1951

Guide for Photometric Testing of Floodlights
Industrial Lighting in a Paper Mill
Engineering for Recommended Brightnesses
Lighting the School Auditorium and Stage
Fluorescent Office Lighting Appraised
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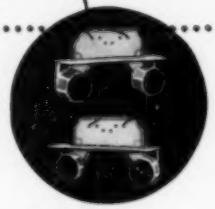
BENJAMIN "MAGNA-FLO" SYSTEMS



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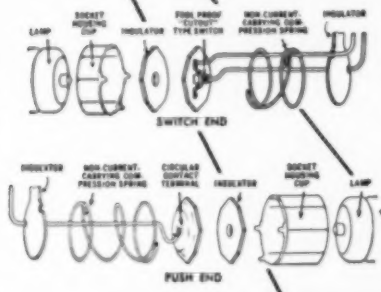

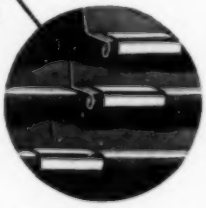

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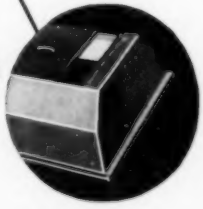

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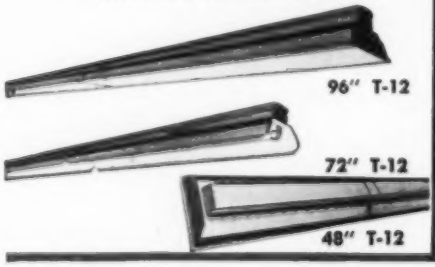

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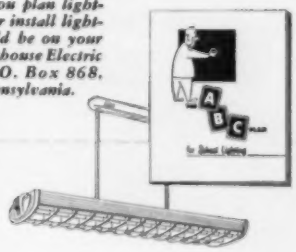

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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

MARCH
1951

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PUBLICATION office 32d Street & Elm Avenue, Baltimore, Md.

EDITORIAL and advertising offices 51 Madison Ave., New York 10, N. Y.

ILLUMINATING ENGINEERING: The Journal of the Illuminating Engineering Society. Copyright 1951 by the Illuminating Engineering Society. Published monthly in the United States of America. Entered as second-class matter at the Post Office, Baltimore, Md. Acceptance for mailing at special postage rates provided for in Section 1103 P.L.&R., Act of October 3, 1917. Authorized July 16, 1918. ¶ Subscription $10 per year plus extra postage to all countries to which second-class postage rates do not apply; single copies $1.50. ¶ Address changes must be received at I.E.S. headquarters by the first of the month to be effective with the issue of the next succeeding month.

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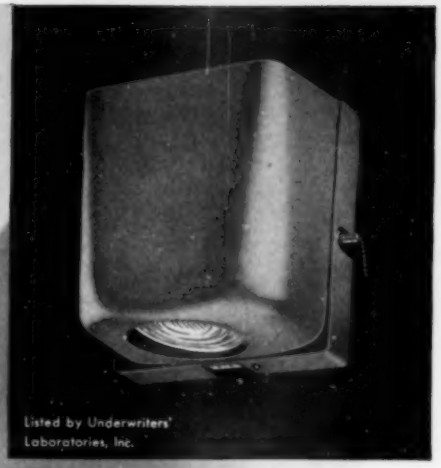

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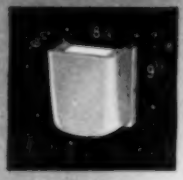

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Engineering a Drafting Office Installation to Recommended Brightnesses

By CARL J. KROEPEL

Quality, rather than high level, was the aim for this drafting office installation. To achieve this, every step of the relighting plan was carefully engineered to I.E.S. recommendations as to illumination level, with brightness ratios the criterion.

WHEN OUR company (Otis Elevator Company, New York) decided to raise the lighting level in the engineering and drafting offices, we had in mind a good lighting installation. We ended up making a two-year study of office environment, and an investigation, including scientific measurements, mock-ups and trials, for all of the interior surfaces and of many different lighting systems — aiming throughout at Illuminating Engineering Society recommendations.

Our engineers, we decided, rated the best we could give them in comfort. All new designs, improvements, and engineering progress of our product originate or come to fruition at their desks. Any efforts we made, or money we spent, to increase their mental or mechanical efficiency we felt was more than justified. For quiet — acoustic ceilings were added. They required not only enough light, we felt, but visual comfort of a high order — quality lighting carefully engineered must be installed. For the drafting division which occupied part of the same area, quiet was also important, but quality lighting was especially needed. Both engineers and draftsmen, however, now work in an environment planned toward the highest standards of all three comforts.

Quality rather than high level was our main objective for the lighting installation, with special reference to I.E.S. recommended brightness ratios. Two items of the visual environment missed this mark. The grey furniture, measuring three foot-lamberts (see Table I) could be lighter. The gloss finish of the linoleum floor as seen in most of the pictures, is more specular than desired for the best practice, giving some reflected image of the luminaire. Since these photographs were taken, how-

Author: Architect, Otis Elevator Co., New York, N. Y.

ever, we have refinished the floors, greatly improving this feature.

With these exceptions, however, brightness ratios between tasks and adjacent surroundings, tasks and more remote surfaces, between luminaires and surfaces adjacent to them, and other areas within the normal field of view, all equal or better the ratios recommended in Table III, page 14, of "Recommended Practice of Office Lighting."*

As will be seen from the values given in Table III, brightness ratios between luminaire (150 ft-L) and ceiling (80 ft-L) are 2:1, looking up directly at the luminaire and ceiling. This is the value determined as "good" by the I.E.S. Committee on Standards for Quality and Quantity of Illumination in Interiors. The minimum ceiling brightness midway between luminaires is 29 ft-L, or a ratio of maximum luminaire brightness (230 ft-L) and minimum ceiling brightness of 8:1; a value of 20:1 is listed as maximum recommendation in the brightness ratios table of the Recommended Practice. In Table III of the Recommended Practice, a value of "10 to 1 between tasks and more remote surfaces" is recommended. In this room, these ratios are:

(a) paper to floor — 28 ft-L to 6.5 ft-L, or 4.3:1
(b) paper to furniture — 28 ft-L to 3 ft-L, or 9.3:1
(c) paper to center of wall — 28 ft-L to 15 ft-L, or 1.9:1
(d) paper to bottom of wall — 28 ft-L to 10 ft-L, or 2.8:1

Between desk top and white paper, the ratio is less than 2:1 (better than recommended). Ratios between the brightest area (luminaire at 230 ft-L) and the floor (6.5 ft-L) are 35:1, where 40:1 is allowed by the Recommended Practice. Furniture somewhat lighter would be required to meet the 40:1 brightness ratio recommended for "anywhere within the field of view." Ratios here are more of the order of 80:1. This may be an opportunity for progressive manufacturers of office furniture.

Ceiling finishes, in relation to our luminaire, required special study. We had by now decided on the use of luminous-indirect lighting. With us the problem of maintenance is a serious one, and in our cost analyses any form of indirect lighting appeared to build maintenance costs if adequate lighting performance was to be maintained. Our problem seemed to meet its best solution in a totally enclosed cylindrical luminaire developed experimentally at M.I.T.

The original 18-foot ceiling was, as is common in older buildings, obstructed with pipes. To overcome this unsightly feature, and aiming also at one of our other comforts—quiet—we based our lighting studies on a metal acoustical ceiling installed 12 feet high.

*Published July 1947 by the Illuminating Engineering Society.

TABLE I.—Cylindrical Plastic Luminaire Lighting Installation Brightness Values — Average of Five Readings.

	Average Footlamberts
Luminaire	
Translucent plastic (at 45°)	230
Translucent plastic (looking straight up)	150
Transparent plastic (at 45°)	150
Ceiling	
Immediately above luminaire	80
Between luminaires	29
Wall	
Upper area	54
Central area	15
Lower area	10
Floor	6.5
Desk top	15
White paper on desk	28
Gray furniture	3
Venetian blinds	
Tilted down	27
Tilted up	14
Typewriter	4.3
Chairs	
Trim	7
Back	1.35

TABLE II.—Brightness Values — Before and After New Installation — Single Readings.

	Before Footlamberts	After Footlamberts
Luminaire		
Inner reflecting surface	375	.....
Outer surface	10.6	230
Lamps	1,800	.....
Wall		
Upper area	7.7	54
Central area	88.8	15
Floor	3.8	6.5
Ceiling	1.6	29 to 80

TABLE III.—Brightness Ratios of New Installation Compared with I.E.S. Recommended Practice.

	I.E.S. Recommended	New Installation
Task and immediate surround	3 to 1	1.9 to 1
Task and remote surfaces	10 to 1	9.4 to 1
Luminaires and adjacent surfaces		
(between luminaires)	20 to 1	2.9 to 1
(directly above luminaires)	20 to 1	8.0 to 1
Anywhere within normal field of view	40 to 1	80 to 1

To study the brightness ratios between ceiling and luminaire, mock-ups were developed for 10- and 12-foot ceilings, in white and colors, and luminaires mounted for measurement. We aimed first at matching exactly, ceiling and the parchment-color of the lighted plastic luminaire. Measurements showed, however, that the cream color acoustic metal, of 63 per cent reflectance, lost about 10 per cent more light than white metal. White acoustic metal of 70 per cent reflectance (an average which includes the holes of the acoustic material) was installed, giving a maximum brightness ratio of 8:1 between luminaire and ceiling.

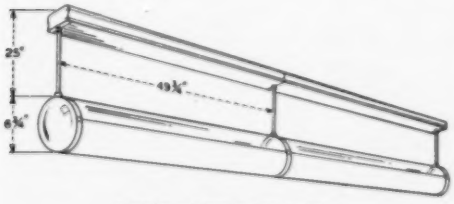
For an integrated interior, all other colors within the field of view were likewise carefully studied. The walls were painted a light neutral green. Desks are a medium grey steel, with tops finished in light "mist green" linoleum (30 per cent re-

Brightness ratios between ceiling and luminaire, before relighting (photograph below) were 100:1 and more. Readings for the buff walls, wood floor and dark mahogany furniture are given in Table II. As shown in the "after" picture at right, brightness ratios now equal or better those established by the Recommended Practice of Office Lighting.

flectance) having non-specular characteristics. To further reduce distracting contrasts on the desk tops, the black telephones were hung from adjacent walls and furniture, removing them from the immediate field of view. Chairs are light green with spring backs. The floor is grey rubber tile. For daylight control, venetian blinds were installed on all windows.

A radical departure from standard practice is incorporated in the design of the luminaire. Ballasts have been removed from the unit and are carried in a wiring channel mounted on the ceiling above each row of luminaires.

The luminaires are essentially a two-lamp, 40-watt design, suspended 25 inches from the ceiling



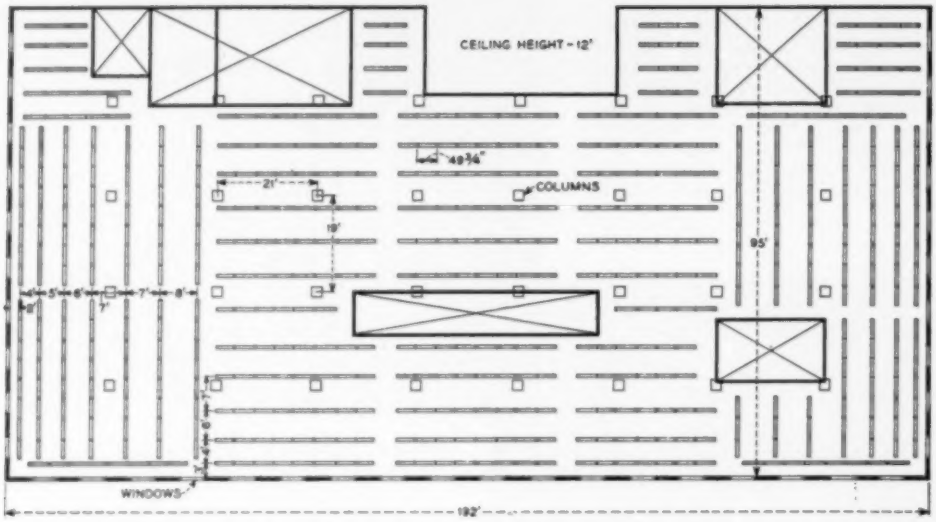
Details of luminaire design.

in continuous rows. The acrylic plastic cylinders which comprise the enclosing unit are, in this installation, 6¾ inches in diameter and slightly longer than four feet. The diffusing (translucent) plastic for the bottom half of the cylinder is white, for which the maximum brightness measurement is 23 footlamberts looking at the side of the unit. Clear transparent plastic comprises the upper half of the cylinder, which encloses the luminaire, preventing dust and dirt from settling inside the unit, thereby alleviating rapid depreciation. Hinges permit lowering of the bottom portion for maintenance. To minimize static charge in the plastic, a special detergent is used for cleaning the plastic, which cleans and de-statizes it at the same time.

Two 40-watt fluorescent lamps are employed in each cylindrical unit, mounted a little below the center of the cylinder, and held by lamp holders recessed in the circular cast metal assembly of the luminaires, which also carry the starters. Color of light source is more or less immaterial, but in this installation standard cool white 40-watt lamps were used. We found that with standard cool white lamps, the diffusing plastic had a pleasing blending effect with the white ceiling. The plastic with standard warm white lamps appeared straw yellow, with a much "warmer" appearance and greater contrast against the white ceiling.

As can be appreciated from the brightness engineering studies made for the installation, our entire lighting environment was quite thoroughly planned. Similar careful trials and studies were also made for the luminaire layout. Complete layouts were drawn up for a number of different arrangements, and for several lighting systems, and illumination levels computed for each.

The final layout was specially engineered for uniformity of illumination from wall to wall over



The graduated spacings from wall to center of the room shown in the layout above provided excellent uniformity of illumination from wall to wall throughout the entire area.

the entire area. With the arrangement devised, a level in the range of 60 footcandles is provided along the wall, close to 60 footcandles in the center of the room, 58 footcandles in the drafting area. The over-all average throughout the entire area is 54 footcandles, after about five months' operation.

The area involved is a space 17,000 square feet in size, with the new ceiling 12 feet high. To obtain uniformity of illumination over this area, the first few rows of luminaires nearest the wall are on closer spacing, gradually extending to greater spacing toward the center of the room. As shown in the layout design, luminaire spacings essentially follow the pattern of:

First row —— 2 feet from wall
Second row —— 4 feet from the first row
Third row —— 5 feet from the second row
Fourth row —— 6 feet from the third row
Fifth row —— 7 feet from the fourth row
Sixth row —— 8 feet from the fifth row

It will be noted from the layout that the rows of luminaires run lengthwise in the central portion of the area, and crosswise at each end. With this arrangement, crosswise viewing of the luminaires is avoided, from the majority of working stations in the room. An additional advantage is the pleasing break this affords, from long parallel lines of light and luminaires.

Thorough planning, and engineering of a high order are required for an installation if it is to meet with the best standards of visual comfort. For our part, we feel the results fully justify the efforts. We are pleased to have had the experience in "brightness engineering"—and incidentally are wiser in the scope and significance of lighting in the work world. We did find, however, that while the literature available is clear enough on what the standards of quality and quantity should measure, there seems to be a serious dearth of published specific information on just what to do to achieve these standards.

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Watch for May issue of IE for information on this all-important lighting problem!

Well Maintained Lighting Systems for Paper Mills

By E. A. LINSDAY

THE LIGHTING of paper manufacturing plants is affected by the rapid rate of depreciation from dust and dirt accumulation on lighting equipment and other room surfaces. The manufacturing processes of the industry create dust and dirt inevitably, and recommendations for lighting must take this into account. It is, therefore, important to install carefully engineered systems and, even more important, to maintain them. In many plants throughout the country, under existing maintenance practices (no regular cleaning), the typical paper mill lighting system delivers about 40 per cent or less of the light that it is capable of producing. This waste of most of the lighting available can be largely overcome with a cleaning and lamp replacement plan, which may cost less than 20 per cent of the operating expense of the lighting system. It is quite possible to realize twice as much light as is realized under typical conditions. This is the possibility that provides the paper manufacturer with an opportunity to step up his production and quality while improving his safety and employee relations at a cost no larger than the light normally wasted.

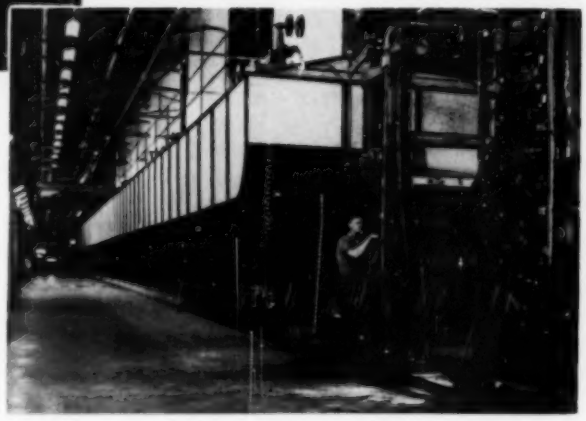
Author: Engineering Division, Lamp Department, General Electric Company, Nela Park, Cleveland, Ohio.

Manufacturing Areas

For the general paper manufacturing processes the lighting system should not only give a good distribution of light over the area, but shadows should not be pronounced. These requirements are, in most cases, best met today by lighting systems employing fluorescent lamps where the mounting heights do not exceed approximately 25 feet. They

One solution to the difficult problem of lighting paper making machinery is shown here. A 150-watt, PAR-38 flood lamp mounted at the edge of the vat to illuminate the machine roll is clearly indicated (right) by its unlighted silhouette. It will be noted that although there is heavy mist present, the lighting effect (below) is good. The self-contained reflector in the lamp is practically impervious to breakage by water or mechanical abuse.

One view of a typical paper making machine (left) is taken under the hood, showing the lighting supplied to the upper part of the machine by under-the-hood illumination. This consists of 100-watt lamps in vapor-proof equipment mounted on 5-foot centers to supply adequate illumination on this portion of the machine. For the more difficult seeing tasks on the lower part, angle floodlights are mounted along the building wall. 750-watt incandescent lamps are used in these reflectors which are spaced on 9-foot centers. The other view (below) shows the general room lighting supplied by semi-continuous rows of 2-lamp 40-watt fluorescent luminaires on 8-foot centers.

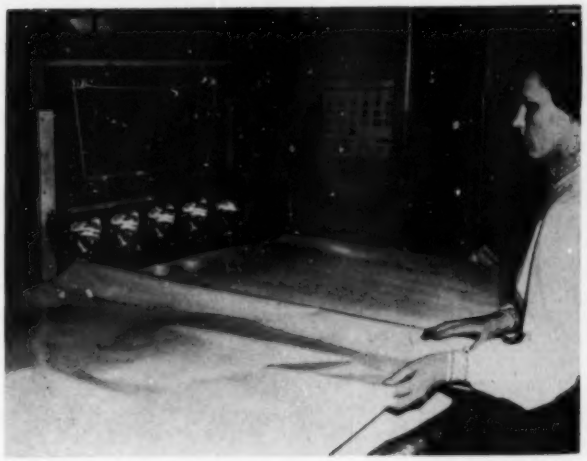


combine high efficiency with low brightness (for eye comfort) and good color rendition. The lighting recommendations usually warranted for areas of this type are in the 40-50 footcandle range and usually utilize two-lamp fluorescent equipment. The standard cool white lamps are usually used except in the critical color discrimination area.

In relatively high bays (above approximately 25 feet) filament or mercury lamps, or a combination of filament and mercury, are often best adapted. They are preferred over fluorescent because of reduced maintenance costs even though the system is somewhat less efficient. The illumination level should usually be in the 40-50 footcandle range.

One of the aspects which may influence the choice of a particular light source for a general lighting system is reflected glare. For example, the use of high brightness sources such as mercury or filament lamps in the calendering areas of paper mills

This shows a typical paper making machine without the hood. In this installation all illumination is supplied by 2-lamp 40-watt fluorescent units. These are mounted in semi-continuous rows (8-foot centers) using two rows of equipment per machine. It will be noted that the fixtures in the aisle between two machines are mounted at an angle to provide better vertical illumination on the sides of the machines.



Automotive foglamps are used for the inspection of finished paper sheets. Where it is necessary to examine the surface of the paper for small imperfections such as wrinkles, tears, spots, the use of these highly directional sources provides modeling or three dimensional effect on the small irregularities in the paper surface. The slight shadows cast by these irregularities make the detection of defects much easier than with ordinary types of lighting. The fog lamps are particularly suitable for this operation because of the sharp cut-off above horizontal.

is usually undesirable due to the high-brightness, specular reflections from the polished surfaces of the rolls.

The heart of any paper manufacturing plant is the paper making machine. Here the pulp is formed into a blanket, the water removed and the paper formed in a continuous sheet. The quality of the paper is primarily determined at this stage of manufacture. It is, therefore, particularly important that the paper making machines be properly lighted. On some parts of the machines it is difficult to supply adequate illumination because of operating conditions. There may be a considerable amount of flying water and pulp which will accelerate dirt accumulations on the lighting equipment if it is mounted close to the machine. This is usually the case, and maintenance should be planned accordingly and accepted as basic to the success of the lighting.

Color Matching

The most accurate representation of color is provided by a light source which does not emphasize or subdue any portion of the spectrum. In other words, a source which has equal amounts of radiation in all colors or portions of the spectrum would be preferred. The recently announced "de luxe cool white" fluorescent lamp is also well adapted to operations where color discrimination, rather than accurate matching is desired. If, however, it is necessary to match two samples it is then desirable to distort deliberately the appearance of the two samples first by lighting them with a source which is predominantly red in spectral composition. If a color match is obtained under these two sources then the samples will match under other lighting conditions. There are a few materials which fluoresce or produce visible light when illuminated by ultraviolet radiation. For this reason, the source which is predominantly blue should also contain enough ultraviolet radiation so that these fluorescent effects can be produced. The source which is predominantly red should not contain ultraviolet. The daylight fluorescent lamp is a logical choice for the bluish component and the reddish component is supplied advantageously by filament lamps.

Reprints of "Contemporary Lighting for Modern and Traditional Interiors"

Attractively bound reprints of the complete I.E.S. Study Report, "Contemporary Lighting in Modern and Traditional Interiors," concluded in the November issue of ILLUMINATING ENGINEERING, are available for distribution in single copies or quantities. This 60-page publication covers the entire field of contemporary residential lighting and is an ideal lighting reference for architects, home lighting specialists and consultants, interior decorators and contractors. Light and power companies, manufacturers of residential fixtures and portables will find it an excellent promotion piece for their preferred lists which include these customers. Single copies up to 10 are priced at $1.00; quantity prices upon request.

Illumination for Sight Testing

By H. W. HOFSTETTER

The illumination needs associated with eye-testing are described in some detail, with general recommendations as to illumination levels and distribution. Emphasis is on the needs in the practitioner's examining rooms. Illumination problems peculiar to the sight-testing practitioner are mentioned. Included also is a discussion of the problem of standardizing illumination requirements for visual acuity testing.

ILLUMINATION FOR sight-testing represents for the most part the problem of illumination in the examining rooms of optometrists and ophthalmologists. Supplementing this are the problems of illumination in visual screening projects such as are undertaken in industries and schools, in drivers' licensing bureaus, in military induction centers, in hospitals, etc. The analysis of the illumination problems in the examining offices of the practitioner may be considered to suffice also as an analysis of the problems in the screening projects insofar as the latter represents a selected phase of the regular practitioner's work.

For the purposes of this paper the examining room problems of illumination may be analyzed in terms of the following categories of special conditions to be met:

1. *Controlled general room illumination which can be changed from complete or virtually complete darkness to a level simulating ordinary daylight.*—Between these two extremes there should be available at least two intermediate levels of illumination, one of which should be sufficient to insure against accidents of stumbling or tripping, to enable the examiner to locate instruments, pencil and paper, etc., and to permit reading of high contrast dials and numbers on the instruments. This low intermediate level will represent the illumination to be used during a major part of a routine refraction. Two or three footcandles, and certainly not over five, at most of the working points in the room should serve these purposes.

For the low intermediate level the illumination source should be extensive in area so as to cast a minimum of shadows. Logically the effective source should be mainly the ceiling itself, but if the ceiling is high, special luminaires must be installed to de-elevate the sources so that the patient's face, and especially the orbital region of the face, can receive illumination without orbital shadows produced by the eyebrows or a prominent forehead. There should be an absence of highlights which may be seen reflected in the pupillary areas of the patient's corneas. In general, this is accomplished if the illuminated part of the ceiling or the overhead luminaire does not extend ahead of the patient's face by an angle of over 30° from the patient's erect face plane.

The installation can be improved somewhat by reasonably diffuse reflectance from the sidewalls and floor, providing that these high reflectance areas also do not extend too far forward. These conditions may be accomplished either by graded reflectances of wall and floor coverings or by carefully installed indirect fixtures.

All wall areas directly ahead of the patient and directly behind the patient should have brightness values low enough to prevent easy discernibility of the details of the surface coverings, such as the seams, the corners, and borders inherent in the construction and architectural design of the room. High visibility of contrast borders in the straight forward view of the patient interferes with the validity of binocular fusion tests and all tests in which the fusion stimuli are to be reduced to a minimum. They also may hamper the examiner insofar as they are seen reflected in the test lenses during retinoscopy.

The wall areas directly behind the patient should also be kept to a minimum brightness so that contrast borders are not readily visible to the examiner during ophthalmoscopy, ophthalmometry, retinoscopy, and other instrumentational tests requiring the use of only one eye of the examiner. In such tests it is desirable for the examiner to leave his unused eye open. To do this easily and efficiently the unused eye should not be exposed to areas having high contrast borders or patterns. Such borders or patterns in the field of view of the unused eye tend to induce a binocular rivalry which interferes with the viewing efficiency of the eye being used in the instrument.

In addition to the low-intermediate illumination level for which the desired conditions have been described, there is also needed a high-intermediate illumination level having essentially the same distribution characteristics. This illumination level should be comparable to that ordinarily prescribed for good working conditions in a typical office or

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home. From 10 to 20 footcandles at most of the working points in the room should serve this purpose. This may be accomplished by a broad semi-direct or semi-indirect luminaire directly above the patient's head, or by implementing an increase in illumination from the system used for the low-intermediate illumination.

The high-intermediate level is especially desirable for the tests in which the patient views upright test cards mounted about 16 inches in front of his face. It also serves for general inspection of the patient's external eye, for illumination of records being studied by the examiner, and for illumination during the adjusting, fitting, selection, and dispensing of glasses. It is this level of illumination that will be routinely used for all general purposes except special testing and during the refraction proper.

Hardly a requirement, but nevertheless a frequent convenience, is the high level of illumination intended to simulate daylight levels. In some offices and at selected times of day this may be accomplished by extensive fenestration, but because of uncontrolled variability this cannot be recommended as a generally satisfactory solution. Carefully localized or supplementary lighting may be made to suffice. Such illumination is useful in analyzing the visual problems of several types of clinical cases, including those whose visual tasks are largely in daylight, those whose work requires high levels of illumination, and those who can benefit from high illumination by reason of subnormal vision handicaps.

This high level of illumination should be of the order of 100 footcandles available directly but diffusely distributed in the patient's face, or on the surface of reading or sight-testing materials held in the patient's face or in his hands. The illumination source should not be an exposed light bulb which may be viewed directly by the patient, as fixations of such sources produce long-lasting and annoying after-images that interfere with immediately subsequent sight-testing.

The availability of complete darkness in an examining room has already been mentioned as the first of the four levels of general illumination, namely (1) complete darkness, (2) low-intermediate, (3) high-intermediate and (4) approximating daylight. In many offices complete darkness is one of the most difficult conditions to accomplish. It has special value in dark adaptation and recovery tests, in projection tests for squinters, in carrying out after-image tests, in cases where fusion stimuli must be absolutely eliminated, and frequently in ophthalmoscopic observations. It is also useful in studying cases of subnormal pupillary responses.

Inasmuch as red light has a minimal effect on scotopic vision, red sources may be installed much as in photographic dark rooms to enable the examiner to carry on testing activities without groping. The red light does not interfere with dark-adaptation tests.

2. *Special light sources.* — Much of the special lighting needed in optometric offices is obtainable in the form of special instruments and lamps sold as ophthalmic equipment. They include special illumination devices for the acuity test charts, tangent screens, perimeters, etc. In addition the examiner has frequent use for easily manipulated light sources varying from a tiny exposed ophthalmoscope bulb for fixation at a distance of 20 feet to a pocket-type flashlight for direct manipulatory illumination in the region of the patient's eye. A detailed discussion of such specialized lights needed in conjunction with sight-testing is beyond the scope of this paper.

3. *Standardized illumination for visual acuity measurements.* — In 1949 a local optometric committee visited 24 separate offices of practicing optometrists. During the visits a survey was made of the lighting conditions under which distant and near visual acuity tests were routinely made in each office. The illumination tests were limited to footcandle measurements of light incident on the chart or screen, that incident on the surround, and that reflected from the screen. Supplementing this information were some measurements of testing distances, the type of acuity measuring instrument, and certain incidental characteristics of the testing situation.

With regard to the illumination, it must of course be realized that the absolute light values obtained by this method of measurement could serve no purpose in a statistical study because of the varieties of instrumentation involved, varying as they did from several types of projectors and screens to printed paper charts and transilluminated opaque letters. The illumination data did serve to demonstrate, however, that all of the practitioners were testing at the photopic level, but that variations within that level were undesirably great.

A factor not taken into account in the survey was the age and/or condition of the acuity measuring apparatus. In the case of projecting-type instruments the age and/or conditions may introduce such sources of variation as the deposit of light-diffusing and light-absorbing particles and films on the lamp, reflector, slide, lens surfaces, and screen; discolorations and altered transparency of the slide film; and the wear and tear on the focusing cams.

set screws, threads, tracks, etc. In the case of the transilluminated types of test charts the age or the condition may introduce such sources of variation as the deposit of light-diffusing and light-absorbing particles and film on the surface of the letters, on the translucent background, on the inner reflecting surfaces of the cabinet, and on the lamps; reductions in the efficiency of the light sources, and errors of replacement of lamp bulbs or differing wattage; discoloration and altered transparency of the translucent material surrounding the letters; and the chipping and fading of the pigmented letters. In the case of the front-illuminated charts similar sources of error may be readily listed.

Finally, it must be pointed out that even under otherwise optimum conditions the correct installation of the apparatus is an important factor, involving control of glare from semi-specular surfaces, angle of projection, distance of projection, location of high-lights, and control of daylight illumination.

The Clinical Problem

From a clinical point of view standardization between patients is not a serious problem. Virtually a complete refraction and visual analysis can be accomplished without even knowing the absolute acuity values. The optometrist demands precise relative acuity data and to that extent has to employ a reliable acuity scale so that he can ascertain the conditions which produce different degrees of submaximal acuity. Any arbitrary or empirical acuity scale can give this information without regard to acuity standards in the population at large. Thus, an optometrist can refract and prescribe as adequately for a person with 20/20 maximum acuity as for a person with 20/15 maximum acuity without having to know which patient has the better acuity. It is only for special advisory purposes that he needs to know who has the better acuity. Certain differential diagnoses involving amblyopia do of course depend on acuity standards, but such standards must be loosely interpreted to have clinical value and are readily accomplished by a small amount of experience with any given acuity testing apparatus. Hence, the fact that acuity measuring conditions vary greatly from office to office does not in itself reflect on the clinical competency of the refractionists so long as the apparatus employed by each refractionist is in itself reasonably reliable.

Certain aspects of clinical analysis do not lend themselves to interpatient standardization. The variations in basic acuity from patient to patient make it necessary to proceed with the optometric examinations on the basis of the patient's maximum attainable acuity rather than in terms of standard acuity. Thus a patient whose maximum attainable acuity is 20/15 will typically experience blurred vision if it is corrected only to 20/20, whereas a patient whose maximum attainable acuity is only 20/25 may well experience clear vision when corrected to obtain this acuity.

The Problem of Standardization

The demand for standardization of visual acuity measurements comes largely from non-clinical sources. Clinically the need arises only when patients are referred or drift from one practitioner to another and attempt to make comparisons. In non-clinical screening procedures in industries and schools and by licensing agencies the standards are usually fixed for the given screening program or depend on calibration of the commercial screening device employed in the project. The practitioner's real difficulty arises only when he attempts to provide a correction to meet the specified requirement, or when he tries to advise the patient that he will or will not pass a given screening or certifying test. In an increasing number of instances the optometrist is relied upon to certify as to the visual acuity obtained by the patient, as in cases referred by drivers' license examiners, sight-saving classes, compensation boards, etc. Then he is in need of a standardized acuity test.

Standards for acuity test chart illumination have been recommended by committees of both the American Optometric Association and the American Medical Association. The A.M.A.[1] recommendation is simply that the illumination level shall not be less than 10 footcandles nor more than 20 footcandles on the surface of a standard A.M.A. chart. The A.O.A. Committee on Standards[2] recommends that the luminance of the test chart should be 10-15 footlamberts, and that the wavelength composition of the illuminant should approximate that of the I.C.I. Illuminant *A*, which is a tungsten lamp operated at 2848°K. The A.O.A. Committee recommendations also include specifications of the luminance of the surround and of the luminance characteristics of the test letters.

At the present time the American Standards Association Subcommittee on Vision is attempting to formulate some recommendations for visual acuity testing standards.

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Advances in Airport Lighting

By W. A. PENNOW

THIS TITLE may be interpreted to mean past or future advances in airport lighting. In discussing the past, measured by present needs, future trends may be properly forecast.

New types of airport lighting today are concentrated mostly on runways and taxiways. Airport beacons, wind and landing direction indicators, floodlights and other accessory lights have remained standard, have improved gradually during the last fifteen years, or have been discussed in the literature. Approach lights, properly classified as airway aids, are not a part of airport lighting.

Runway lights, signal lights seen as sources by the pilot, have become the most important of all lighted aids on airports. Starting with about two candlepower, they have grown brighter until now some have peak candlepowers as high as 180,000.

Part of these increases in brightness have resulted from logical calculations, some from exhaustive flight tests, and some from no reason at all. Currently, runway lights fall into three broad classes, with variations. These are:

1. *Low intensity*, usually flush or semi-flush contact lights, symmetric or asymmetric distribution, with peak signal about 1000 candlepower.
2. *Medium intensity*, usually elevated runway marker lights, asymmetric distribution, with peak signal about 2000 candlepower.
3. *High intensity*, elevated runway marker lights, asymmetric distribution, with peak signal over 10,000 candlepower.

Most low intensity runway lights were installed before and during World War II. Nearly a quarter-million of these lights are installed on airports all over the world, probably more than the total of all other types of airport lights. Their use continues at runway intersections and similar areas where elevated lights cannot be tolerated.

Medium intensity lights are used on all sizes of airports, and usually on all runways except those equipped or planned for instrument approach use.

High intensity lights are used on all instrument runways, and on some non-instrument runways at major terminal airports.

Medium intensity runway lights are currently covered by CAA specification L-802. Two distributions are specified; one, Fig. 1, with a 30-watt, 6.6 ampere lamp; the other, Fig. 2, with a 45-watt, 6.6 ampere lamp. The average performance of present equipment is shown as an envelope over the specified distribution.

In the figures, zero vertical is parallel to the plane of the runway; and zero lateral is normal to the runway center line.

Note that the specification curve provides a safety factor for service conditions, including allowances for blackened lamp bulbs, dirty lenses, and current at lower end of supply tolerance. The average performances shown are laboratory results,

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Section Engineer, Aviation Lighting, Westinghouse Electric Corp., Cleveland, Ohio.

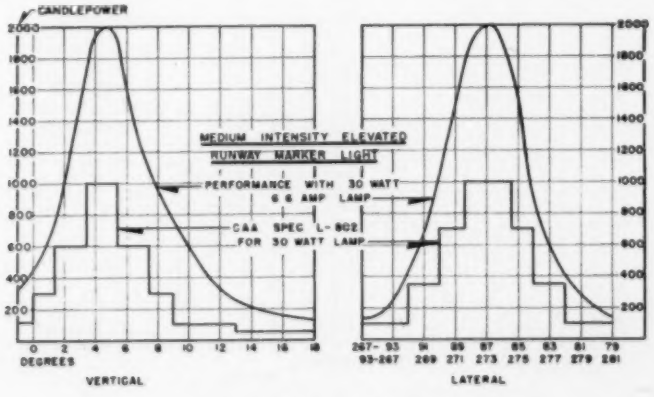


Figure 1.

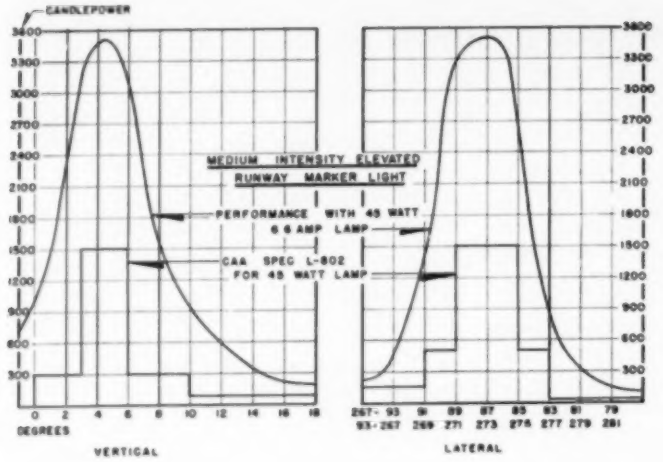


Figure 2.

with clean lenses and rated initial lumen output of lamps.

Sadly enough, general practice is to use 30-watt lamps on all non-instrument runways, class 1 to class X airports, blithely ignoring the obvious fact that a DC-6, Constellation or Stratocruiser has a larger turning radius and higher approach speed than a Cub, and thus requires more candlepower for circling and line-up.

Fig. 3 shows a suggested specified distribution and average performance for a new intermediate intensity runway marker light that would provide lighting more suitable for non-instrument runways on large airports.

The relative visual ranges, in feet, with one-mile visibility, of the distributions shown on Figs. 1, 2, and 3 are 4200, 6300 and 7900 for circling; and 11,000, 12,000, and 13,000 for line-up, respectively.

Airplane speeds and turning radii are increasing, traffic densities are going up, pilots have less time to look for lights, and must see them at greater distances. The time is here, now, to start bringing the lighting of non-instrument runways up to a useful level.

The inadequacy of current lighting on non-instrument runways has caused pilots to urge installation of "Runway Reference Lights," Fig. 4, very high candlepower distinctive groups of lights at each end of each runway, separately controlled, so the pilot has a chance of promptly locating the

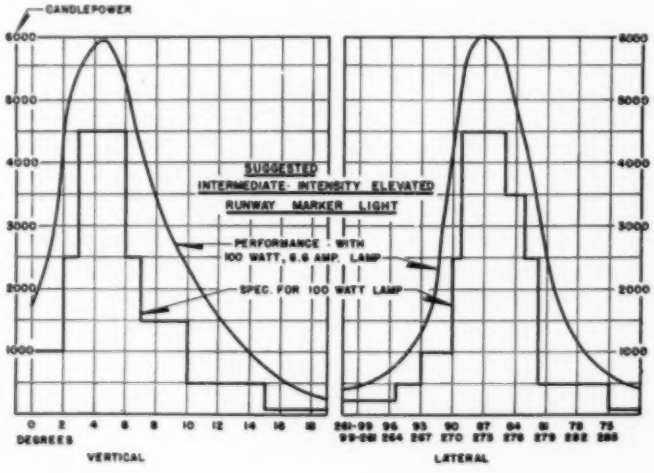


Figure 3

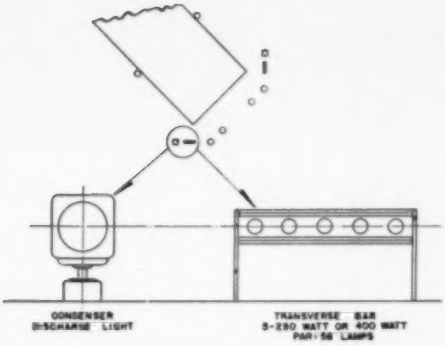


Figure 4. Runway reference light assembly.

threshold of the runway he is to use. Higher intensity runway lights will not remove the need for these powerful threshold markings, but will more clearly outline the runway so less time will be wasted in lining-up.

Clear weather traffic densities with movements, landing or takeoff, down to five-minute intervals can be handled on the average runway equipped with medium intensity runway lights. Many airports report movements down to three-minute intervals being handled. Pilots are not happy with three-minute intervals in a continuous traffic flow. Too many airplanes are in the traffic pattern at one time for safe handling, unless the runway is visible and the threshold clearly identified from any point in the traffic pattern.

As marginal weather operations increase, intermediate intensity runway lights will be mandatory to maintain proper traffic flow. Of course the installation will be higher in cost than medium intensity lights. Operating costs should be about the same, as the higher energy and lamp costs will be offset by the reduced maintenance frequency due to a greater percentage of operating hours on less than 100 per cent brightness. At most terminal airports the revenue produced by one more airplane movement per week due to better lights will repay the difference in installation costs within a period of approximately one year.

As an advance in airport lighting, it is urged that major airports having—or expecting—traffic density requiring any movements at less than five-minute intervals take steps, now, to —

1. Use 45-watt lamps in their medium intensity runway lights with clear lenses, and 100-watt lamps with green lenses. The change from 30- to 45-watt lamps will usually require only physically changing the lamps. Where tapped insulating transformers are used, the taps must be changed. The change to 100-watt lamps in the threshold lights will require changing the insulating transformers at each light from 30/45-watt to 100-watt rating. In some cases it may be necessary to increase the size of the constant current regulator or brightness control ratio transformer, or sectionalize the circuit and add a regulator or transformer. In any case the improvement in lighting is far greater than the relative cost of the change.

2. Plan for the installation of intermediate intensity runway lights on all new construction or modernization of non-instrument runways.

High intensity runway marker lights are covered by one of three CAA Specifications, L-818, L-819, or L-820. Figs. 5, 6, and 7 show the specification values, and the enveloping curves show typical characteristics of representative units.

While most airport lighting engineers are prone to think of these three types of high intensity lights as interchangeable, they are not similar, each having features for solution of specific problems.

Specification L-818, controllable narrow beam bidirectional, is excellent for use in areas with many competing lights. The very high candlepower and narrow horizontal beam requires good operat-

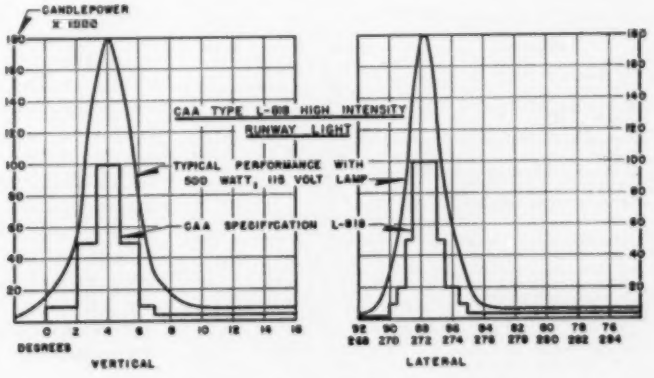


Figure 5.

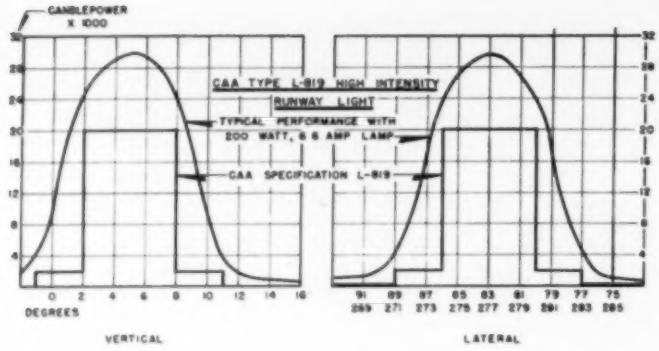


Figure 6.

ing technique by skilled tower men to insure coverage of the required region of guidance.

Specification L-819, fixed wide beam bidirectional, is the most popular, but has low peak signal and should not be used in areas having competing lights.

Specification L-820, adjustable medium beam unidirectional, has sufficient candlepower for use in areas with competing lights, can be adjusted for optimum performance on any width runway and any angle of approach (glide path angle). Opposite beams can be adjusted separately in case the angle of approach differs for opposite ends of a runway.

Table I lists various characteristics pertinent to the proper selection of the type of high intensity runway light for any specific airport.

Effectiveness against competing lights is a function of candlepower and definite beam formation. Reasonably sharp cut-off at the edge of the beam increases effectiveness, as the lights appear to "pop-up" when alignment is reached.

Different characteristics work best with different obscuring media. Dry fogs, smoke and haze offer similar obscuring effects, appearing as pure interference or diffusion, with refraction and reflection minimized. Wet fogs having large water particles, snow and rain may also be grouped, as obscuration is by reflection and refraction rather than diffusion. Bidirectional units create self-interference under these conditions by illuminating the reflecting and refracting particles beyond each unit by the back beam from it, thus raising the visual threshold candlepower requirement, and reducing their effectiveness.

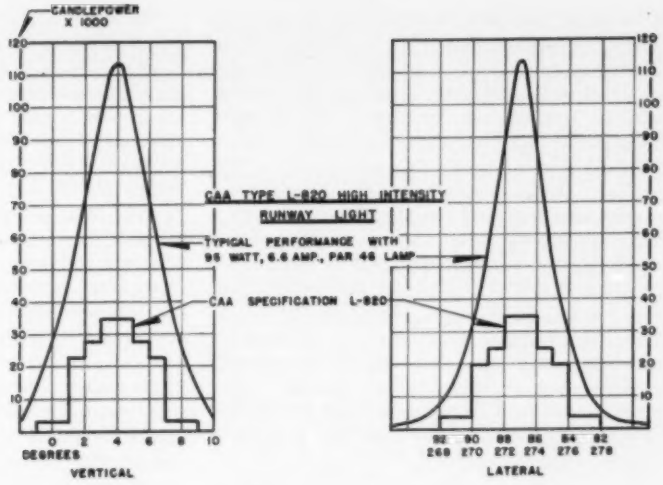
Circling guidance is obtained from the off-runway side of the lights and is poor on all three types of units, with the L-819 type almost useless. An interesting point here is that engineers of the Port of New York Authority, operators of New York International Airport, recognized this and developed special photometric requirements for their L-819 type units, which increased the off-runway light from 100 to 1000 candlepower in the circling guidance region.

Region of guidance is a new term to many airport lighting engineers. Applied to any single high intensity runway light, the region of guidance may be defined as an area extending toward an incoming airplane, bounded laterally on one side by a vertical plane coinciding with the runway center line and on the other side by a vertical plane diverging two degrees outward from the runway edge and passing through the vertical axis of the light to intersect the runway edge. The vertical boundaries consist of one plane diverging three quarters of one degree downward from a plane fifty feet below and parallel to the glide path angle for the particular runway, and a second plane diverging one half of one degree upward from a plane fifty feet above and parallel to the glide path angle, the latter intersecting the runway plane at the light. The lower edge of the region of guidance thus intersects

TABLE I.

Condition			L-818	L-819	L-820
Peak signal, candlepower, actual			180,000	30,000	114,000
Visual range, feet, in ½-mile visibility			3,450	2,710	3,330
Effectiveness against competing lights, relative			100	40	95
Effectiveness in dry fogs, smoke, haze, relative			100	70	95
Effectiveness in wet fogs, snow, rain, relative			80	60	100
Circling guidance, marginal weather, relative			100	50	100
Region of Guidance coverage, on 200-foot wide runway, distance in feet with visibility of:	¼ Mile	H	1,300	1,050	1,550
		V	1,600	1,550	1,750
	½ Mile	H	660	650	975
		V	1,000	825	1,025
Optimum angle of approach, (glide path) degrees			3	2½	2-6
Optimum spacing between rows, (runway width)			100-200	190-220	100-250

Figure 7.



the runway surface about one thousand feet ahead of the light when the glide path angle is two and one half degrees, and less when the angle is greater.

Note that each light along a runway stands by itself. Overlapping distribution patterns are not additive or complementary, as these are signal lights, seen as individual sources.

Runway width may be a determining factor in selecting the type of runway light. The L-818 and L-820 types, having adjustable toe-in, are less limited than L-819 with fixed toe-in. Close attention to region of guidance coverage in various visibilities for the specific runway width, or spacing between rows, is necessary in making the right selection.

The peak candlepower developed by representative units under each of the three CAA specifications is a subject for many heated arguments between engineers when applying any one type. Many of those who argue lose sight of some basic facts, and the reasoning, or lack of it expounded becomes rather feeble. The advantages for each of the types lie more along other lines, as shown in Table I. The relative visual range, in feet, of average peak signal candlepower of each of the three types in various visibility conditions is shown in Table II.

Now, if we translate these data into terms applying to runway lighting, some very interesting comparisons may be made. Table III shows the number of lights in a line along one side of the runway that the incoming pilot has a chance of seeing, or "carrying" as he arrives over the threshold and proceeds down the runway to land and slow down to taxiing speed. Assuming, of course, that the approach is "in the groove," lenses are clean, lamps are new and are delivering rated lumens.

The most interesting point shown by Table III is not the nearly insignificant difference in number of lights visible due to great increases in candlepower, but the point that should jolt airport lighting engineers out of their complacency is that the old clear weather standard of spacing lights 200 feet apart along the edges of a runway is wholly inadequate for visibilities of less than one-quarter mile. Note that Table III assumes that the pilot is at the threshold. Add about fifty feet of altitude to the figures shown, and the number of lights visible to the pilot over the threshold will be only about half that tabulated.

Candlepower alone is not a solution to making more lights visible. Reduced spacing, at least at the approach end of the runway, is a far more sane answer. With full electronic aids, and adequate approach lighting, we should be thinking about operations during one-eighth mile visibilities, and

TABLE II.

Type	Candlepower	1/8 Mile	1/6 Mile	1/4 Mile	1/2 Mile
L-818	180,000	735	1,195	2,075	3,450
L-819	30,000	600	1,025	1,680	2,710
L-820	114,000	705	1,165	2,000	3,330

TABLE III.

Type	Candlepower	Number of Lights							
	In Visibility of With Spacing of	1/8 Mile 100′	1/8 Mile 200′	1/6 Mile 100′	1/6 Mile 200′	1/4 Mile 100′	1/4 Mile 200′	1/2 Mile 100′	1/2 Mile 200′
L-818	180,000	7	3	11	5	20	10	34	17
L-819	30,000	6	3	10	5	16	8	27	13
L-820	114,000	7	3	11	5	20	10	33	16

so arranging the plans, circuits and load carrying values that one-sixteenth mile visibility operations may be made possible by adding the intervening units. If serious thought is given to the over-all problem, it is obvious that on all high intensity installations, plans, circuits, energy supply capacity and locations must be based on spacings of not over 100 feet. At the instrument approach end of the runway, the first 1000 feet should be planned for not over 50-foot spacing. Some airline pilots' committees are urging that spacings of 25 feet be used for the first 200 feet, 50 feet for the next 800 feet, then 100 feet for the remainder of runway length. Table III shows that this is about the minimum for reasonably safe operations during one-sixteenth mile visibility conditions. Pilots generally agree that they need at least ten lights visible in the line of runway lights from the time the threshold is identified until touchdown.

When we plan for adequate lighting under these very low visibility conditions we must become more critical of the photometric distribution of the various types of lights as regards proper coverage of the region of guidance, that volume of space extending from the lights toward the approaching airplane, in which the airplane will be as a result of an instrument approach.

As illustrated in Table I, there are serious deficiencies in the photometric performance of our present high intensity runway lights. As the performance exceeds the specification requirements, it is apparent that the specifications will need changes to better fit them to the requirements for adequate coverage of the Region of Guidance in weather of one-quarter or one-eighth mile visibility.

As an example, by changing the toe-in of the beam on the average L-819 type unit from seven degrees to three and one-half degrees, the Region of Guidance coverage distance, horizontal, is increased from 1050 to 1600 feet with one-quarter mile visibility, and from 650 to 900 feet with one-eighth mile visibility; both about optimum for the beam shape and candlepower obtainable with the available lumens; and the runway width range is increased from 190-220 to 100-220 feet. Further, better use of presently wasted flux to increase the light needed for circling guidance would increase the effectiveness of the unit in marginal weather.

The region of guidance coverage, horizontal, in weather of one-quarter mile visibility, 200-foot wide runway, for each of the three present types of high intensity runway lights is shown on Fig. 8. Data are also shown for the L-819 type unit with toe-in changed to three and one-half degrees.

As another advance in airport lighting, it is recommended that all airport lighting engineers:

1. Give full consideration to all factors involved when selecting the type of high intensity runway light for a specific airport.

2. Change their thinking from clear weather conditions to weather conditions of one-quarter, one-eighth, or one-sixteenth mile visibility, depending on the expected date of the next complete revision of runway lighting for the specific airport, 1953, 1958 or 1963 respectively. These are tentative target dates for achievement of scheduled operations under visibility conditions of one-half, one-quarter, and one-eighth mile, respectively, as set up by the Radio Technical Commission for Aeronautics master working plan.

It is further recommended that airport lighting design engineers:

1. Reconsider their Performance Specifications and make

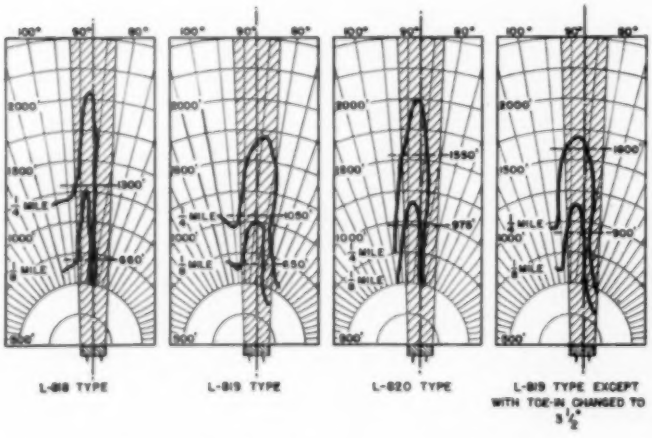


Figure 8. Visual range, distances in feet at which lights may be seen, during daylight object visibilities of one-quarter and one-eighth mile. Light at edge and end of runway, 2½° glide path, touchdown point 1000 feet from threshold, 200-foot-wide runway. Curves show lateral coverage of region of guidance.

such changes as are necessary to provide proper Region of Guidance coverage under visibility conditions down to one-eighth mile, bearing in mind that specifications should predate operational needs by at least ten years. Airports cannot afford to change lighting systems at lesser intervals.

2. Start developing performance specifications and equipment suitable for use in visibility conditions of one-sixteenth mile, or less, to maintain a ten-year lead on operational requirements.

The past decade has seen great improvements in the effectiveness of runway lighting. Present high intensity lighting, except for circling guidance, is good, and quite adequate for today's operational requirements. It must be made much better to be as adequate a decade hence.

Taxiway lighting currently is in a sorry state. Most taxiway lights are very low brightness, usually less than ten candlepower, intended for clear night use only. Most have symmetric distribution, and the few with asymmetric distribution have patterns similar to runway lights. One type uses cold cathode gaseous tubes arranged to define the taxiway by shape arrangement. All of the presently used lights are of questionable value during daytime, or during restricted visibility, day or night.

The I.E.S. Sub-Committee on Taxiway Lighting is actively testing various new methods at New York International Airport. This effort, however, is to bring the performance up to present operational needs. Completely new concepts are needed if taxiway lighting is to be useful in moving airplanes off of and on to an instrument runway during instrument weather.

The author gratefully acknowledges the excellent analytical work by Mr. G. M. Kevern, Headquarters Air Materiel Command, used in this paper. Also the counsel and guidance of Captain E. A. Cutrell, American Airlines, Inc., and Captain John Gill, Eastern Airlines, Inc., expressing the pilots' views and needs, present and future.

DISCUSSION

H. J. Cory Pearson*: I have to take exception to the last sentence of the first paragraph of Mr. Pennow's paper. As the airport is the area on which the airplane lands, all landing aids are essentially part of the airport, including approach and threshold lighting.

We can always look to Mr. Pennow for a well-thought-out paper, and to me this paper is remarkable for the omissions. Mr. Pennow does not give consideration to the interpretation problems presented by varying runway widths, of gaps resulting from intersections, or the problems of zone marking of touchdown and warning areas. He also gives scant consideration to the problems of threshold marking.

This paper deals effectively with the sore problem of adequate side visibility for circling approaches, and points out the necessity for provision of adequate wiring capacity and provision for closer spacing for future use under lower minimums, but I would like to have the advantage of Mr. Pennow's analysis of the other problems mentioned.

L. C. Vipond*: In the second paragraph of Mr. Pennow's paper he states that "approach lights, properly classified as airway aids, are not a part of airport lighting." Quite a few expert pilots, lighting engineers and experimentalists closely associated with the flight testing of visual aids under conditions of poor visibility will be inclined to argue this point. As a matter of fact, Lieutenant Colonel K. H. Kalberer, USAF, in his recent paper entitled "A Statement of the Approach Lighting and Marking Problem and Certain Possible Conclusions," has this to say, in talking of the point in the approach where the pilot needs the assurance provided by visual aids:

> "The author believes that the approach lighting and marking problem begins here and encompasses all phases of maneuvering from this point through the landing. Hence, he does not believe it realistic to consider approach lighting, threshold lighting, runway lighting and runway marking even as closely allied problems. They are integral parts of *one* problem."

Colonel Kalberer is at present Chairman of the ANC Visual Aids Subcommittee and has been up to his "hub caps" in this work for a number of years.

Mr. Pennow's suggestion for an "intermediate intensity" runway marker light is not a bad idea. There is considerable merit in his suggestion to provide better lighting for non-instrument runways on large airports. It is pointed out that this can be done — and has been done — by putting high intensity runway lights on non-instrument runways at the bigger airports. Instead of developing a new "intermediate intensity" light for this application it is recommended that the present L-819 unit be used. The L-819 unit is now being produced in rather large quantities and in many cases the price has dropped to where it is quite comparable with L-802 medium intensity units. The L-819 unit with a 100-watt lamp could be a satisfactory answer to this problem.

Mr. Pennow speaks of the L-818 high intensity runway light as a "controllable narrow beam" unit. The CAA has approved two different makes of units under Specification L-818 and the laboratory photometric curves for one of these units show very definitely that the main beams are both wider and higher than any of the test curves made for either the L-819 or the L-820 units. Therefore, it seems somewhat inaccurate to call the L-818 light a "narrow beam" unit.

In speaking of circling guidance, Mr. Pennow states that "circling guidance is obtained from the off-runway side of the lights and is poor on all three types of units, with the L-819 type almost useless." Some visibility curves plotted by CAA engineers showed an entirely different picture on this score. The L-819 and the L-818 units both meet the region of guidance circling approach requirements as drawn up by the ANC Visual Aids Sub-Committee. The L-820 unit fell short of meeting these requirements, the reason being the L-820 unit provides circling guidance only through the small medium intensity lamp on top of the unit. The main beam lamps do not contribute to this off-side light at all.

*Lighting Section, Civil Aeronautics Administration Experimental Station, Indianapolis, Indiana.

*Office of Airports, Civil Aeronautics Administration, Washington, D. C.

In approving high intensity runway lights made by many different manufacturers it has been found that the performance curves from laboratory tests of the units vary quite widely. In many of the lamps the filaments are not uniform at all; positioning of the socket or lamp holder is not always accurate in relation to the lenses; and lenses taken from the same mold can vary appreciably in performance.

Because of these factors the photometric performance curves of the units actually in use at the airports today will vary up and down. That is why the CAA specification curves may seem somewhat conservative. We believe Mr. Pennow would have been somewhat more realistic had he confined his "typical performance curves" closer to the CAA specification curves, particularly as regards "Fig. 7" in his paper.

In converting photometric performance into visual range, as Mr. Pennow does in "Fig. 8" of his paper, it would have been desirable had he disclosed the exact factors he used in making the conversion. It is possible we are not using the same slide rule but nevertheless we have not been able to arrive at the same visual ranges shown in Fig. 8.

We would like to agree very heartily with Mr. Pennow in his statement that "candlepower alone is not a solution to making more lights visible." His recommendation to reduce the spacing to not over 100 feet (instead of the present 200-foot spacing) is a good one and it may very well be that we shall be spacing them in this manner in the near future. Such spacing would, of course, increase the cost of an installation and if it had not been for this factor we would have had 100-foot spacing long before now.

F. C. Breckenridge*: Congratulations are due Mr. Pennow on the preparation of such a constructive and stimulating paper on a subject that many aviation lighting engineers might consider worn-out. As Mr. Pennow ably demonstrates, the subject of runway marker lights is not only not worn-out but is a most timely one. Moreover, as his treatment clearly implies, it is not a single subject but two; the problem of providing guidance for an airplane circling an airport is quite different from the problem of guiding the pilot who is approaching to land from a direction already aligned with the runway. Of the two the landing problem is nearer a satisfactory solution than the circling problem.

I agree heartily with Mr. Pennow's statement that runway lights placed on 200-foot spacing "are wholly inadequate for visibilities of less than one-quarter mile." In the I.C.I. meeting of 1939 the British urged seriously that contact lights should be placed on a 25-foot spacing. Some of us were already convinced at that time that a spacing of 100 feet was needed and the testing we did for the CAA at Indianapolis and Nantucket during 1940 and 1941 confirmed this. On the other hand there are good reasons for believing that placing the lights too close together is a disadvantage rather than a gain as the lights tend to blend into a streak which may not give as good guidance as distinct lights symmetrically placed on opposite sides of the runway. This is one of the problems calling for study.

The matter of candlepower distribution, on which Mr. Pennow lays stress, is another problem needing study. In general, I agree with the emphasis he gives to selecting lighting units with regard to the required region of guidance but I trust he does not mean to assert, as one paragraph under this caption seems to imply, that it is only necessary for a pilot to see marker lights on the side of the runway nearer to him. The whole theory of guidance with contact lights requires two rows to be visible for height, center-line, and roll guidance. There has been a beginning of experimentation with marker lights accompanied by red and green satellites. With such paired lights, it may turn out to be practicable to land alongside of one row but the testing has not proceeded far enough to warrant any opinion as to the feasibility of the idea. In any case, careful studies should be made of the visibility of the different types of lights. Our previous efforts to make such studies mathematically have convinced us that much can be learned from these analyses but they should be based on isocandle diagrams and not on simple horizontal distribution curves. It is also important to have agreement on the values of the constants to be used in the formulae and to this end the Committee on Aviation Lighting should support the proposal advanced by Mr. Kevern to have such constants agreed upon. After the computations have been made, some of them should be checked by ground visibility observation in fog as the correlation of theory and testing has been exceedingly weak in this field.

Circling guidance has received less sound consideration than the landing problem. Pilots have frequently expressed their convictions as to its importance and have given the impression that they believe the engineers might easily redesign the units so that all the lights would be as visible at all times during the circling operations as the rows are during landings in good weather. Such an achievement is, of course, quite impossible. The good visibility on the approach is achieved by concentrating the flux into a comparatively small angle and if it were spread back again the result would be to make the lights nearly as invisible on the approach as they sometimes are in circling. To provide good circling guidance from runway marker lights in even one-mile visibility is not within the range of the practical.

The effectiveness of runway marker lights suffers from another difficulty which may perhaps be overcome. The natural pattern of two rows of white lights is not conspicuous when there are highway lights within the field of view. The remedy would seem to be to devise a more conspicuous pattern; a pattern that could not be a broad roadway with lights on both sides, or two parallel roadways near each other. The simplest solution would be to use quadrant color filters on the outside of the units so that the pilot will see a green-white-red line on the near side of runway with a white line beyond it. It is quite probable that the gain in conspicuity would more than offset the loss of intensity resulting from the filters. An experiment carried out at the National Bureau of Standards more than fifteen years ago suggests a more conspicuous characteristic for marker lights. Mr. Angier, now of the CAA, and I constructed a model in which lights in line were connected in rotation to three series circuits. These circuits were fed with three-phase power through three variable reactors which were varied with a period of one or two seconds and with a phase difference of 120 degrees between those variations. The reactors were so chosen that no lamp ever became entirely invisible. The resulting effect was that of waves of light flowing down the line in either direction we chose. It was both conspicuous and characteristic. Moreover, it can show the direction of landing unmistakably without any arbitrary code. For an installation made with high intensity lights, the added cost of the system would be small in comparison with the other costs of such a system.

The improvement of the visibility of runway marker

*Civil Aviation Lighting, National Bureau of Standards, Washington, D. C.

light systems is of interest to several different groups of engineers. The manufacturers' engineers are interested as they will have to produce whatever is to be used. The military services are interested as purchasers and users. The CAA Office of Airports is interested as the regulatory agency responsible for satisfactory civilian performance. The CAA Technical Development and Evaluation Center is interested as a civilian development group. Our National Bureau of Standards Civil Aviation Lighting Group is interested in the technical aspects of the problem. Would it, perhaps, be well to establish a temporary steering committee to coordinate the interests of all these groups in a project to determine performance specifications for the optimum intensity distribution for the runway light units and the most conspicuous characteristics for assembled systems? If such a committee is practicable, the I.E.S. Committee on Aviation Lighting would seem to be the appropriate sponsor.

In conclusion may I extend my compliments to Mr. Pennow on proposing progress where it is much needed.

A. B. WINTERS*: In discussing Mr. Pennow's paper, I'd like to add my two cents' worth by commenting particularly on the data for the L-820 Runway Marker. The specification L-820 does not specify maximum or minimum lamp sizes, but is strictly a performance specification. Mr. Pennow states that "candlepower alone is not a solution to making lights more visible." This statement, and the values in the tables indicate that increased candlepower is of value.

As we all know, sealed-beam type lamps are made in a range of sizes, the PAR-46, the PAR-56 and the PAR-64. The size of the bulb limits the amount of energy that can be successfully consumed within the bulb. It is a known fact that the PAR-56 has a much more efficient reflector contour and, watt for watt, more lumens can be produced. The PAR-56 costs no more than the PAR-46; in fact, it may be a little less. With the larger, more efficient envelope of the PAR-56 it is practical to go to higher energy lamps and produce much greater candlepower — even to 500,000 with the same distribution as the 95W or 100W PAR-46.

With the greater candlepower, it would be possible to add three more units, visible under conditions of one-half-mile visibility and 200-foot spacing, and one more unit of one-eighth-mile visibility and 200-foot spacing. The slope-line approach lights use the 250W and 400W PAR-56 lamp, and it seems logical to adopt one size lamp for all equipment so that a standard lamp-holder could be adopted.

My comments are in line with Mr. Pennow's second recommendation that "performance specifications be developed for one-sixteenth-mile visibility or less." We now have a unit in the L-820 specification, with modification for circling guidance which can add materially to this goal. Mr. Pennow does not give credit to this possibility, however.

In conclusion, I would like to ask Mr. Pennow his source of information for this data in Table I, II and III. This is not established in his paper.

MARTIN A. WARSKOW**: Mr. Pennow indicates that the subject of high intensity runway lighting is quite controversial. This is true and is quite confusing to airport owners when confronted with the claims made for various units. One advance in airport lighting, I hope, will be the gradual elimination of the controversy.

From the airport owners' (the customers') standpoint, the decision which high intensity runway light to use should be made on the basis of (1) performance, (2) initial cost, and (3) operating cost.

I believe that a factual analysis will show that the only practical difference in the units performance-wise is as follows:

(1) The movable beam unit with remote control (Specification L-818) will be superior to the other units for good weather operations because the main beam can be toed out and away from the approaching pilot's eyes so that the units can be operating at a higher intensity. However, this same factor may be a disadvantage in bad weather operations because the control tower operator may use the wrong setting for the toe-in so that the lights do not operate at their maximum efficiency.

(2) The fixed focus wide beam three-lamp unit (Specification L-820) can be used for a wider variation of conditions than either of the other units because of the adjustments possible on beam toe-in and elevation and the possibility of using various lamps. However, the average airport uses 200-foot runways for which all units are suitable so that this is an advantage only in certain cases.

(3) The fixed focus wide beam one-lamp unit (Specification L-819) when built strictly according to its specification will have inadequate circling indication.

The controversy surrounding the whole subject of high intensity runway lightnig could soon be removed by general realization of certain facts. First, improvements which have been made in the fixed focus one-lamp unit (Specification L-819) particularly in its circling indication, along with other improvements now under development by the U. S. Air Force will make this unit's performance practically equal to the present movable beam (Specification L-818) and fixed focus three-lamp (Specification L-820) units. Second, initial costs and operating costs are decidedly less with the fixed focus single lamp type of unit.

This would certainly indicate that all efforts should then be concentrated on the one type of high intensity runway light with benefit to all.

W. A. PENNOW*: Mr. Pearson and Mr. Vipond comment on the author's separating the approach and runway lighting problems. CAA officially segregates these problems, as the Office of Airports, which has jurisdiction over runway lighting, does not deal with approach lights; and the Office of Airways, which is responsible for approach lighting, is not concerned with runway lighting.

Mr. Pearson's wish for additional data on interpretation problems, marking of warning areas, thresholds, and touchdown areas, is well founded. There are little data available on these subjects, but as each would command a full length paper, they cannot be treated with here.

Mr. Vipond's recommendation, that the L-819 with a 100-watt lamp be used as an intermediate intensity runway marker light, will bear close scrutiny. Specification L-819 requires a minimum of 75 candlepower in the off runway half-hemisphere, using a 200-watt, 4800-lumen lamp. Circling guidance might be less than satisfactory if a 100-watt, 1800-lumen lamp were used. Note that Fig. C suggests a minimum of 225 candlepower in the useful zones for circling guidance.

Information on the second Type L-818 unit, referred to by Mr. Vipond, was not available when the paper was prepared. The wider beam spread has advantages and disadvantages. Improved coverage of the region of guidance should be obtained, while the wide beam may cause some

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**The Port of New York Authority, New York, N. Y.

*Author.

loss of effectiveness against competing lights, especially if the edge of the beam is less sharp. Also, the importance of the controllable beam feature may be minimized by the wider spread and lower peak candlepower.

It appears that the defense of the L-819 circling guidance is strictly mathematical while runway lights are used at airports where it is quite possible that more than one airplane in the circling pattern may be seeking guidance at one time. Apparently the ANC Visual Aids Sub-Committee has also not fully considered this point. With any given visibility condition, and at any specific brightness step, a specification that infers a desirable ratio of more than 50 to 1 between the candlepower in the region of guidance and that seen by the pilot of a circling airplane may permit units giving unsatisfactory circling guidance.

In the case of L-819, calculations are usually made on the assumption that the specified 75 candlepower is available for circling guidance, forgetting that, under any visibility condition where 75 candlepower would be useful, the lights *cannot* be operated at full brightness without setting up blinding glare to a pilot on final leg of approach. If the lights are dimmed to accommodate the latter, then the light available for guidance to other airplanes in the circling pattern may be less than one candlepower.

The L-818 unit used for data in the paper had about 3000 candlepower at full brightness available for circling guidance, or an approximate ratio of 60 to 1 between peak beam and circling candlepower. Specification L-818 sets the ratio between minimums at 50 to 1. Specification L-819 sets this ratio at 266 to 1. Specification L-820 is a different proposition, as the brightness of the main beam and the circling light can be varied separately. Here the ratio limits are governed by the medium intensity bidirectional element. This ratio is set at 20 to 1 by Specification L-820. The substitution of the suggested intermediate intensity light for the medium intensity light as the bidirectional element in Specification L-820 might result in a very useful unit. Note that the suggested ratio for the intermediate unit is 20 to 1 in Fig. C.

In all this rebuttal it should be understood that this accentuation on circling guidance is not necessarily in agreement with the ANC Visual Aids Subcommittee's preliminary definition of the region of guidance for circling approach, but is based on providing the best possible coverage of the areas likely to be occupied by an airplane, the pilot of which is trying to maintain visual contact with the lighted runway while on the down wind and back legs of a circling approach.

Regarding Mr. Vipond's list of additional variables which require that specification minimums be conservative when compared to typical performance curves, it should be noted that only the non-uniformity of lamp filaments would affect Fig. G. Also, the PAR-46 lamps used for these data carried a 500-hour design life rating. Similar PAR-46 95-watt lamps with a shorter design life rating should consistently exceed the performance data shown.

The question of checking calculations, raised by Mr. Vipond and Mr. Winters, emphasizes the point mentioned by Dr. Breckenridge that a common base line be established. All calculations used in Tables I, II, III and in Fig. H employ the value E = 2000 mile-candles, as applied to Allard's Law.

In reply to Dr. Breckenridge, the paper was not meant to infer that the pilot need see only the lights on his side. It was intended to show that some current units probably could not be seen on his side, and that changes in performance were necessary to insure that he could, at least, see those on his side.

Mr. Winters seems overly optimistic on the advantages of higher candlepower. If he will study Fig. H, I think he will find that a peak candlepower of 500,000, with otherwise the same distribution as the 95-watt PAR-46, would not increase the distance coverage of the region of guidance now shown for the Type L-820 unit, regardless of the number of units added to Table III. A comparison of curves on L-818 and suggested revision of L-819 show that factors other than candlepower must be considered.

Mr. Winters should make a more complete study of comparative data on PAR lamps. For a discussion on the relative efficiencies of PAR-46 and PAR-56 reflectors, he is referred to the paper "Reflector Contours for Pressed Glass Lamps"* by P. F. Dietz. The statement that, with the PAR-56, "watt for watt, more lumens can be produced" than with the PAR-46 is doubted. Usually, with a given wattage at a given voltage or current and a given design life, the larger the lamp envelope the less efficient the lamp. Perhaps Mr. Winters is trying to compare a PAR-56, 100-watt, 75-hour design life lamp with a PAR-46, 95-watt, 500-hour design life lamp. Mr. Winters should note that the PAR-56 lamp is further handicapped by having a cover glass with pressed lens elements, thus introducing another variable as pointed out by Mr. Vipond. In the PAR-46, all glass components are plain.

The proposal of higher wattage is good, but it is urged that instead of striving for very high candlepower, close attention be paid to the demands of the region of guidance, attempting first to attain proper distribution.

Mr. Warskow's conclusion that all efforts should be concentrated on one type of high intensity runway light, when combined with comments by Mr. Vipond and Dr. Breckenridge, points to Utopia — wherein one runway light might serve as a medium, intermediate or high intensity runway light, perhaps by changing the lamp size, or wattage, for each class of service. While there is much to be learned about runway lighting, and a realistic definition of the region of guidance for circling approach must be established, it may not be too early to start planning for such Utopia—realizing that there will be many progressive steps.

This paper attempts to set forth the good points of existing types of runway lights, comparing typical performance to specified minimum requirements. Also it attempts to list deficiencies and suggest remedies for obvious shortcomings, while pointing out the need for future development. It was prepared in a manner to bring evaluation to a common level, and in so doing to provoke comments.

The author wishes to express sincere thanks to all those offering discussion, and feels honored by the amount of concurrence with the expressed views. Perhaps the procedure suggested by Dr. Breckenridge can be activated, and a Steering Committee appointed to assist in carrying out the recommendations made in the paper.

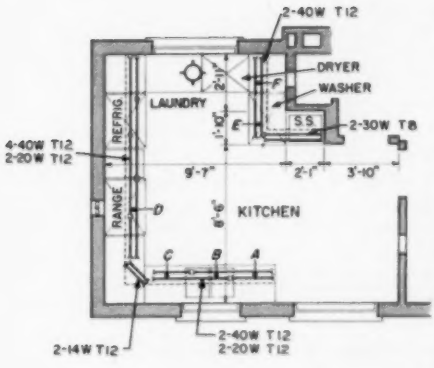
*Presented at the 1950 National Technical Conference, Pasadena, California.

1951 National Technical Conference—August 27-30—Washington, D. C.

Soffit Lighting of a Kitchen

LIGHTING OBJECTIVE: To provide shadowless illumination on all work surfaces and satisfactory general illumination throughout the room.

Installation at Cincinnati, Ohio.



Plan View.

General Information: The kitchen is 13' 3" x 15½' x 8'. Ceiling, furring and walls are painted a light yellow and the cabinets are white. Sink top and work surfaces are light blue Formica. The floor covering is light blue marbleized linoleum with a yellow feature stripe and dark blue border. Draperies are dark blue with a yellow trim.

Installation: Two rows of 4500K fluorescent tubes arranged in a staggered pattern as shown in the plan view are recessed above glass shielding over all the work surfaces to give a continuous line of light. The soffit opening is covered with ⅛-inch diffusing glass (Libbey-Owens Ford Industrex).

An incandescent ceiling luminaire (Moe Bros. #M410) containing two 60-watt lamps is mounted near the laundry area.

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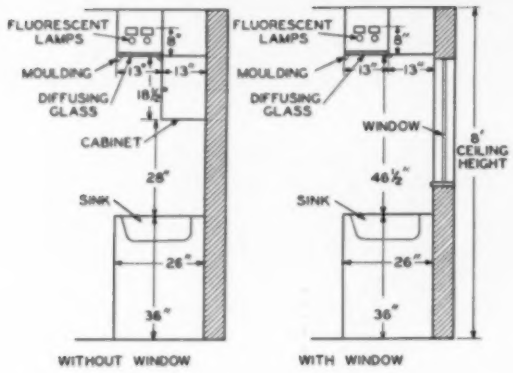

Detail of Soffit Lighting.

Illumination and brightness measurements takenafter approximately 180 hours of operation were follows:

Location (see plan view)	Footcandles on Working Surface	Footlamberts on Cabinet Doors 12" Below Glass Panels
A	60	193
B	65	(window)
C	85	158
D	80	193
E	80	132
F	60	237
30-inch plane down center length of room	35	—

Lighting data submitted by Miss Stella M. Fetzer, Cincinnati Gas and Electric Company, Cincinnati, Ohio as one solution to a lighting problem and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society
51 Madison Avenue, New York 10, N. Y.

Series XVI 3-51

Lighting the School Auditorium and Stage

By CARL J. ALLEN

With many schools improving their classroom lighting conditions, considerable attention is being directed to the specialized problem of lighting the auditorium and stage. A range of options in lighting the school auditorium and stage are here presented, analyzed and illustrated. The equipment reviewed ranges from that suitable for the more complete installation to that which is specifically suited to a minimum budget installation.

IN TOTAL there are more stage and dramatic presentations on the school stage than anywhere else in the country. In addition to the various types of stage presentations, the school auditorium is used for speaker assemblies; for motion pictures, both visual educational and recreational; and in some cases of crowded conditions for study hall purposes.

Auditorium Size

While the school auditoriums in the past have been quite large there are visual requirements which tend to limit their size. These limitations are shown in Fig. 1. Where large assemblies are necessary, they frequently can be housed in the school gymnasium where large seating capacities are being provided. This leaves the auditorium to its role of being a more intimate theater where good seeing conditions can be provided.

Auditorium Lighting

The lighting requirements in the auditorium may be divided into two parts. One is the need for general atmosphere lighting wherein suitable brightness patterns are created which give the visual impression of a well lighted esthetically pleasing room. The second need is for supplementary audience illumination, *i.e.*, light which is controlled over the seating area and which is of suitable quantity for the seeing that may be done there. Flexibility in the lighting installation is desired. For general assemblies, or before curtain time when programs are being read and friends recognized, a level of ten footcandles is recommended. For stage and motion picture presentations a fraction of a footcandle is generally sufficient. If the auditorium is to be used for study purposes, thirty footcandles is recommended.

As the annual hours of use of the school auditorium are generally not sufficient to justify the use of fluorescent light sources and because they cannot be easily dimmed to black out, the incandescent type light source is ordinarily used for auditorium lighting. Fluorescent lamps do have the advantage of being a slender extended source available in a variety of efficient colors and, hence, are used where these features are desired.

Atmosphere Lighting.—Atmosphere lighting in the auditorium may be accomplished in a variety of ways as shown in Fig. 2. One trend appears to be toward the use of step-back ceiling coves in which the light is directed forward, with the light sources concealed from the normal view of the audience. Color may be incorporated in these coves using reflectors with individual lamps or reflectorized lamps with color roundels. Various levels of illumination and mixtures may be obtained by operating the circuits on dimmer control. A very useful combination is a light blue and a light amber circuit. With these, either a warm or a cool character may be introduced and in addition by mixing a near white can be obtained. The surfaces to which the light is directed should be light and fairly neutral in color if a full range of color effects is desired.

Indirect lighting either from suspended fixtures or from wall urns or coves can be pleasing in quality and suitable for auditorium general lighting purposes. As it is generally desirable to reduce the number of suspended luminaires to a minimum in the larger auditoriums, specially designed luminaires may be used which incorporate a number of fairly high wattage lamps. In such equipment, or in wall units, the reflector type lamps have been used to minimize the light depreciation due to dust settling in the lighting equipment. Where maintenance is difficult due to the mounting height, disconnect louvering hangers are useful.

The area beneath the balcony may be lighted by large size coffers of low brightness. Where equipment cannot be recessed in the balcony soffit,

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: General Electric Company, Nela Park, Cleveland, Ohio.

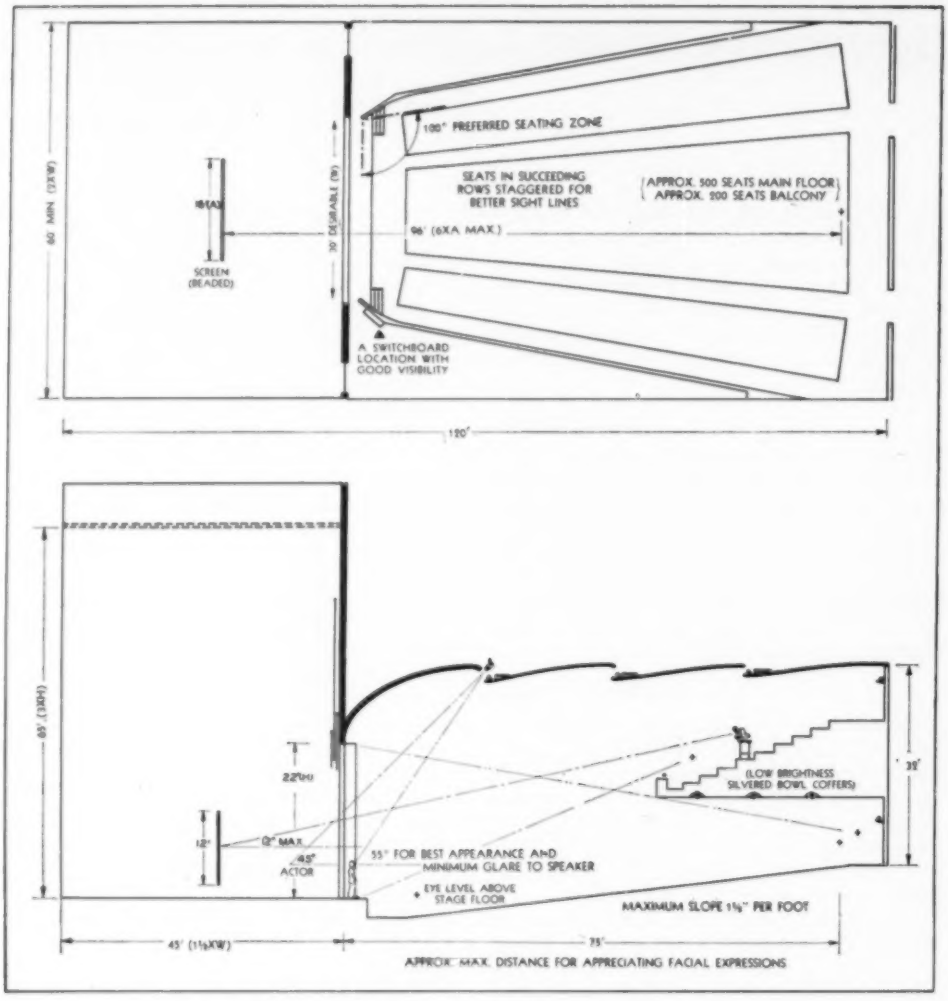

Figure 1. School auditorium dimensions limited by visual requirements.

a cove located across the rear wall containing reflector lamps directed out over the underside of the balcony can be employed.

Audience Lighting.—The atmosphere lighting system may be very effective in building a pleasing brightness pattern in the room, and yet deliver relatively few footcandles over the seating area. The needed additional lighting over this area may be accomplished by direct lighting. It should be so controlled in distribution that, even under darkened room conditions, a reasonable level can be produced without the audience being unduly aware of the light sources. A means of accomplishing this is by the use of narrow beams of light tilted forward from overhead units in which the source brightness is concealed from view, Fig. 2.

Stage Lighting

The requirements of stage lighting are varied, hence the equipment and controls should permit as great a degree of flexibility as possible. A typical complement of stage lighting equipment for a moderate size school stage is shown in Fig. 3. The general order of importance of the various elements

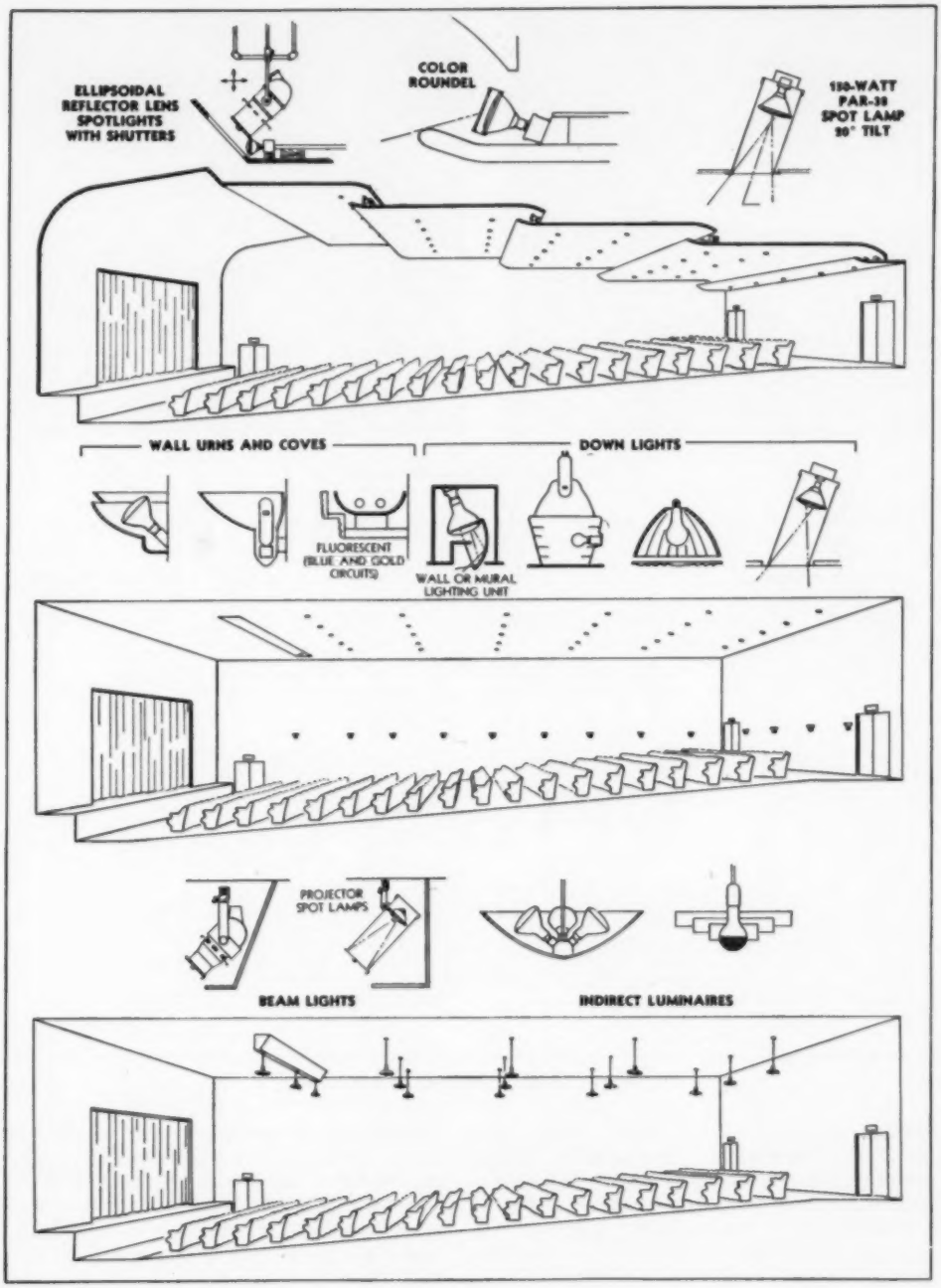

Figure 2. Options in lighting a school auditorium.

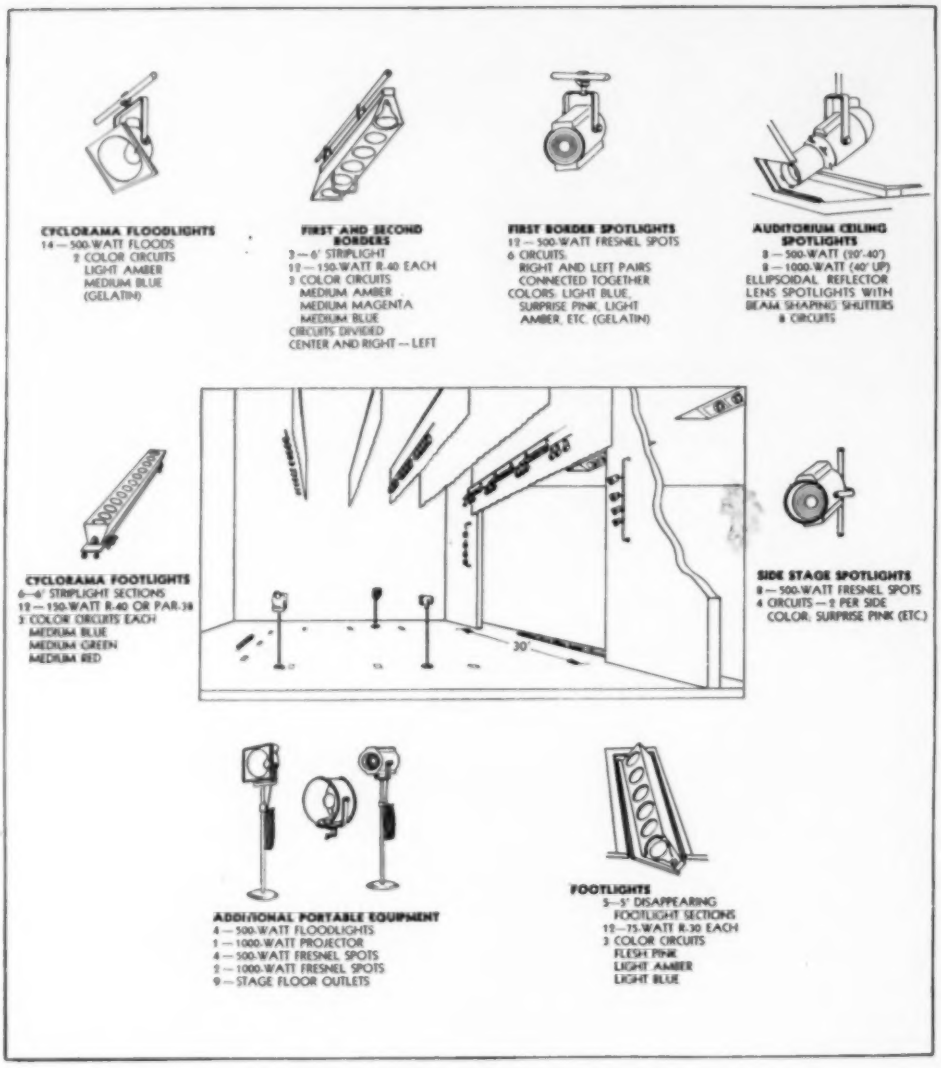

Figure 3. Lighting equipment for a school stage.

is offered as being: (1) first border spotlights, (2) first border striplights, (3) auditorium ceiling spotlights, (4) rear stage overhead floodlights, (5) supplementary portable equipment—spots, floods, striplights, (6) intermediate border striplights and spotlights, (7) side spotlights, (8) footlights. Items 1, 2, 3 and 4 represent the minimum initial equipment usually required.

First Border Spotlights.—Because of their location these lights are directed down from an advantageous angle onto the acting areas. An average stage can be divided into six acting areas, three across and two deep. Each area needs to be lighted from two spotlights, generally one from each side of the stage. Frequently one source is equipped with a cool color filter such as light blue, and the other with a warm color such as light amber or flesh pink. As the equipment is relatively close to the areas being lighted, fresnel type spotlights are desirable because of their soft edge beams.

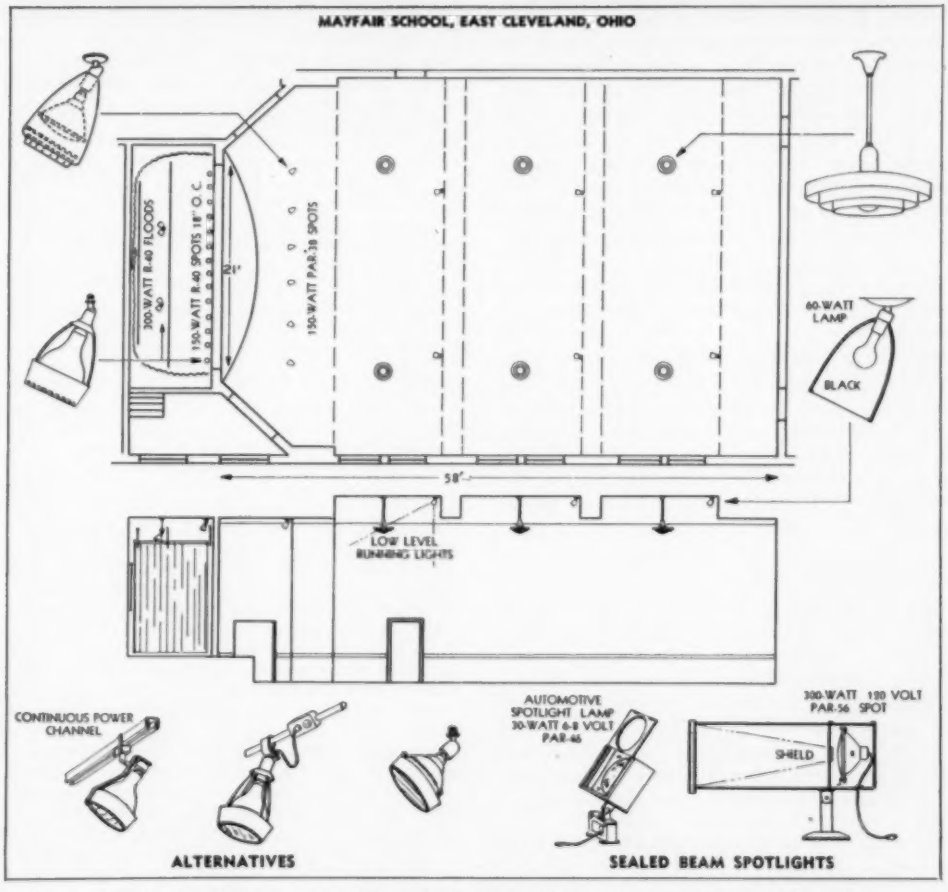

Figure 4. Lighting a small school stage with reflector and projector lamp accessory equipment.

Border Striplights.—These units are used for the purpose of toning the set and filling in those areas not illuminated by the individual spotlights. They are arranged on several color circuits such as amber, magenta, and blue in the medium transmissions. Each color circuit needs its own dimmer control for flexibility in mixing colors. For minimum conditions two circuits are suggested, one a medium amber and the other a medium blue. Provisions for interchanging these colors with other color filters are desirable.

Auditorium Ceiling Spotlights.—Controlled beam type spotlights are recommended for this service. One of the most effective ways of accomplishing this is by the use of ellipsoidal reflector lens spotlights. With such units the beams can be confined to a specific acting area, and stray light can be kept off of the prosceniun arch by means of framing shutters. Another suggestion is to use sealed beam type spot lamps in housings designed to absorb the direct stray light. These spotlights are usually located in the auditorium ceiling so that their beams form a 45° angle with the horizontal when aimed at an actor standing slightly behind the first border lights. For spotlighting speakers on the stage apron this angle should be about 55°. Two such units located about 60° apart horizontally give pleasing facial shadows and at the same time produce minimum disturbances to the speaker. Surprise pink color filters are often used with these units to enhance the complexion tones of speakers and actors.

Rear Stage Overhead Floodlights.—These units may be of the border striplight type or large reflector floods. They are generally used to light the cyclorama or background scenery. Color is obtained by gelatin in frames which slip into the units. For good uniformity and to minimize emphasizing any wrinkles or irregularities in the cyclorama surface they should be placed well forward.

Supplementary Portable Equipment.—The most useful auxiliary type equipment for use on the stage is the fresnel type spotlights which can be adjusted as to narrow or wide soft edge beams. Where a soft shadow, broad flood of light is desired, the open reflector floods with color filters or diffusing screens are used. Where sharp edge beams of various shape are needed the ellipsoidal reflector lens spotlights are particularly useful. For illuminating backgrounds from the floor, portable striplights similar to the border striplights are used.

The Small School Stage

A minimum budget auditorium and stage relighting installation is shown in Fig. 4. The reflector and projector lamps are employed for the stage lighting as they give a suitable degree of control, are convenient, and represent a low original cost. In suitable accessory equipment with provision for aiming and a means of holding color filters they serve for many applications which do not require the flexibility attainable with the regular stage lighting equipment.

Control Equipment

On the school stage the desire is to get the maximum flexibility for a given investment. For flexibility in circuit control with a practical number of dimmers, cross connect or plug-in-type panels are popular. Silent type circuit breakers are desirable for on-off control and for providing the necessary overload protection. For flexibility in wattage loading for full range dimming the autotransformer or saturable reactor type dimmers are generally employed today.

It is well to establish a complete plan, even though all the lighting and control equipment may not be installed initially. In this way the addition of equipment will be most effective.

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DISCUSSION

S. W. Brown*: With a brevity and completeness which is typical of Mr. Allen's presentations, he has here covered a subject which genuinely deserves to be discussed.

The school auditorium represents one of the bright spots in the "dreary" school life of our youngsters. "Assembly" is usually synonymous with action, adventure, or important moments as the student progresses from being deeply impressed by some slight-of-hand performer to the day he receives his coveted diploma. It is gratifying to observe that our school authorities usually endeavor to build auditoriums in accordance with their manifold and important usage.

Why, may we ask, does Mr. Allen divide his auditorium lighting requirements into two parts—atmosphere and audience lighting? Why should we have the expense of two systems? Cannot one system be made, sufficiently flexible to fill the requirements of both? As in so many other instances, let us turn to nature for its advice. What is an "overcast" sky but a large diffusing source of relatively low brightness

*Nambusch Decorating Co., New York, N. Y.

and subsequent intensity? But the dark and overcast day is not the type of day we would choose for merriment or the like. The bright sunny day is our choice for growth and pleasure. What is the sunny day illumination but the direct radiation from that great light source the sun, coupled with a good amount of "sky light"? — Two systems, direct plus diffused general. Compare these, if you please, with Mr. Allen's "atmosphere" (general) and "audience" (specific) lighting. Because "atmosphere" lighting seldom requires an excess of 10 footcandles of illumination, it can generally be supplied from indirect or concealed sources. The higher intensities which are required for such auditorium usage as study and examination lighting in the order of 25 to 35 footcandles can, with practical limitations, only be supplied by direct, preferably concealed, recessed sources. Mr. Allen offers a wide choice of methods and equipment from among which any school may find answers to its needs within its particular budget.

The "Under Balcony Lighting Problem"—Light sources of high surface brightness, whether exposed or recessed in the under-balcony ceiling can be definitely detrimental to observance and eyesight by creating veiling glare. Unfortunately for the students, too many such installations have been seen in the past. Mr. Allen's recommendations calling for low brightness sources, whether direct or indirect, are strictly in order.

"Audience Lighting"—Mr. Allen recommends for this application "narrow beams of light tilted forward from overhead units, etc." This application of downlights is satisfactory in many cases. One limitation is that the forward light beams may interfere with the screen illumination as in cases where only a shallow stage is possible. Another means of obtaining good shielding in a unidirectional auditorium is by sectional baffling of the downlights creating steep cut-off angles from the audience point of view, but allowing normal beam spread sidewards and forward.

One stage lighting problem is touched upon by Mr. Allen, which heretofore has been seemingly neglected. That is the need for good illumination of the speaker or actor standing on the front part of the stage nearest the audience. The tendency has been to rather overlight the stage behind the proscenium, but completely neglecting this, often much more important front area. No stage can afford to allow this neglect. Spotlights, recessed or otherwise are a "must" for the front stage because it is from here that all the most important announcements, speeches, or lectures are usually made.

Reflector lamps, with color filters, have been proven a Godsend to the stage of ambitious ideas but limited means. Until more permanent stage lighting equipment can be afforded, the simple reflectorized lamp stands in good stead.

Mr. Allen's paper, inclusive of its simple and yet so explicit illustrations, might well be recommended for general use and should find its way into the hands of many school planners whether city fathers, educators, architects, or engineers.

STANLEY MCCANDLESS*: Mr. Allen's paper brings up to date a subject long overdue. Over twenty years ago the late A. L. Powell prepared a paper on lighting for the non-professional stage and there have been a number of papers on special projects such as the lighting of Radio City Music Hall since then. But Mr. Allen deals with a field of lighting that largely lies outside the practice of the illuminating engineer.

If I seem to differ with some of the details, I want it clearly understood that this paper meets a definite need if it makes the average illuminating engineer aware of two things. (1) That footlights and borderlights are of secondary importance to spotlights and have been for twenty-five years and consequently red, white and blue may be patriotic but distinctly outmoded as a pattern for laying out color banks on a switchboard. (2) That the intense activity of schools in the dramatic field should indicate that the word "Theatre" does not always apply to a movie house and that young people working on the stage as part of their school activity deserve to have up-to-date equipment designed, selected and installed with the same respect for value received and appreciation of modern practice as that provided in the chemistry laboratory or gymnasium of any school. It may come as a distinct shock to some of the lighting fraternity and taxpayers that the lighting equipment usually installed on the school stage is at least a 50% waste of money. Cut the borders and foots in half or one quarter and put the money saved in a few good spots and dimmers. Why should enthusiastic youngsters have to put up with technical difficulties the professional theatre worked out of years ago?

Too often the simple answer lies in the fact that the school building code has not been brought up-to-date; that there has been too little precedent of good practice and worst of all that the specifications writer has never worked on the stage and would probably find it too difficult to depart from the old methods anyway.

Here is a paper with a concrete set of suggestions that constitute good modern practice. The chief trouble with them is that in the space allowed there can be very little giving of reasons. The drawings speak volumes and should be studied carefully.

I should question a stage depth much greater than the proscenium width. The narrow auditorium makes a deep one. A 45° width still gives good night lines. The "55° for best appearance" seems a little arbitrary, unless the angle is also at least 45° to the side. Anything between 30° and 60° in longitudinal section and up to 90° from the axis in plan works. In fact the ageing ingenue must have flat lighting from straight ahead if the wrinkles aren't to show too much.

I like the idea of *atmosphere* and *audience* lighting for the auditorium but I think the latter is by all odds more important than the former except in a movie. It is most important that both should be on dimmer; therefore, fluorescent sources except in the cold cathode form are ruled out. Reflector lamps and their uses are well illustrated. I suspect there would have to be a great many of the narrow beam reflector-lamp downlights for good coverage.

I should like to see a larger drawing of Fig. 3, and a schedule of equipment including a switchboard and a patch (inter-plugging) panel.

The idea of the small theatre layout seems highly practical compared to the old foot and border light systems, but I am inclined to believe that two or three good spots would soon pay for themselves.

"Control Equipment" could well have an article by itself because few people can grasp the importance of dimmers. I would like to suggest just for argument's sake that the "Small School Stage" layout (Fig. 4) implies at least twelve dimmers and the large layout (Fig. 3) should have at least thirty, preferably forty-eight including eight or nine of large capacity units for eye. lighting. Where the theatre activity is considered more important as a teaching

*Century Lighting Co., New York, N. Y.

tool electronic control with scene presets and fading is not beyond reason. It is the natural way to control light so that it becomes a vital dramatic element.

C. SCHAMMEL*: I feel that this is an excellent article in that it puts the emphasis on certain phases of lighting which can be considered to come under the latest principles of stage lighting practice which we have found are very definitely not understood by most of the architects and consulting engineers who have control of the design of new auditoriums.

Dealing with the auditorium phase, we commend the pertinent comment that if large assemblies are required, they should be housed in the gymnasium or elsewhere rather than ruin the use of the auditorium for an intimate theatre by making it the 1200-1600 capacity type that has unfortunately become customary in California schools.

On page 3, under auditorium lighting, it is worth emphasizing that the atmospheric lighting should not attempt to do more than give a pleasant indirect light aiming for only a few footcandles, with the balance of the desired footcandles delivered more efficiently by direct lighting.

On page 3, under the requirements of stage lighting, I might take exception in the small point of the order of importance, in that we would say the auditorium ceiling spotlights and the first border spotlights would be first and second, with the balance of the equipment following as he has them. Unfortunately, the momentum of designing stage lighting with borderlights and footlights, only, as was necessary in the days before efficient spotlights, continues. It usually takes a great deal of explaining and persuasion to get even a few auditorium spotlights into the specifications of a job. The fact that he has placed footlights under the last (8) is in accord with my views, but invariably the principal of a school demands the footlights for graduation. I feel that when price is the essence on a job the footlights can often be left out, just so a proper opening is framed in the stage so the footlights can be installed in the future without major changes. For straight dramatic production footlights are not often used today, but for operettas and costume plays they then become necessary to give proper toning to the costumes.

In conjunction with the emphasis on flexibility and portability of equipment, we often suggest the use of disappearing footlights which are built with a four-and-one-half-foot-long removable striplight. This striplight can be removed when the footlights are not to be used and can be used as an extra borderlight section, or set in floor brackets and mounted on the floor as eye. footlights.

On page 4, under borders and striplights, I would like to emphasize my agreement with Mr. Allen's choice of medium colors to give the advantage of the extra transmission. However, to be exact, the secondary colors should probably be used (amber, magenta and blue-green) so that a fairly full spectral range is possible with dimming. I disagree with his contention that two circuits are possible for minimum conditions, since if borderlights are to be used at all they should be furnished in at least three color circuits because of the three color system in the spectrum. If we are speaking of minimum conditions then groups of wide angle floodlights could be used on two circuits in place of borderlights at a great savings, but only as a temporary compromise.

We have been pushing for a good many years the advantages for having combination holders for the color filters, so that the dramatics teacher can have a choice of roundels in the primary hues, averaging approximately twenty per cent transmission; stripped glass filters in the secondary hues, averaging approximately 35 per cent, or gelatines, with approximately 54 per cent average in the secondary hues, and a full range of 70 colors for special effects.

Page 5, under rear stage overhead floodlights, we agree with Mr. Allen when he said that the floodlights, to minimize wrinkles on the cyclorama, should be placed well forward, and we would like to make a more specific suggestion that they should be placed a minimum of 10 to 12 feet downstage of the cyclorama because a number of jobs have been poorly lighted because the cyclorama batten was placed only five or six feet from the eye. We feel that it is usually better to recommend three circuits of eye. floodlights.

If the architect was requested to design a smooth rear wall to a stage, we have found that if it is finished in a rough, sand floated, white cement plaster it can be used very successfully as a plaster eye., which always adds extra possibilities to the flexibility of the stage when the extreme depth is desired.

In addition to the equipment suggested as supplementary portable equipment, we feel that it is important also to have backing floodlights, which are very similar in ellipsoidal section to the eye. units but are smaller in diameter and take the G-30, 250- to 400-watt lamp. These units are made with special clamps to allow mounting on the back of flats to illuminate "backings" where the use of cumbersome floor stands and larger floods would be difficult because of space limitation.

We also feel that a very useful item is a rolling tower, which is really nothing more than tall floor stands mounted on a weighted base with casters, since the direction of the light must often be from a point higher than the standard extension stand.

To save the cost and time of painting backdrops, many of the small schools and colleges are using Linnebach type scene projectors. This is usually an economical investment since it more than repays itself after one production that requires many short scenes.

Also, in order that there should be a standardization in extension cable and plugs and caps, it is becoming accepted practice on the West Coast to use stage pockets with twist-lock receptacles with 20-ampere capacity, rather than the former outmoded heavy duty porcelain plugging receptacles.

We agree that on the very small stage or platform it is possible to use the reflector and projector lamps with a very economical compromise method; but we have found from experience that the average school budget frowns on the use of borderlights and footlights using the reflector lamps. No one denies the efficiency and advantage of always having a new reflector in perfect condition, but when they come to relamp for the first time the much higher cost of the reflector lamp as compared with the standard inside frost lamp has resulted in our having kick-backs. Several years ago many of the schools were specifying striplights with these reflector lamps, but recently less than 10 per cent have been interested enough in the extra efficiency.

One unit that we have had a great deal of success with for small stage use has been a special adjustable holder with a pipe clamp that takes the side prong, PAR-38 lamp, since it has the extra advantage of a very small over-all length and can easily be concealed in the auditorium in the tormentor position or behind a very shallow proscenium arch.

*Associated Lighting Service, San Francisco, California.

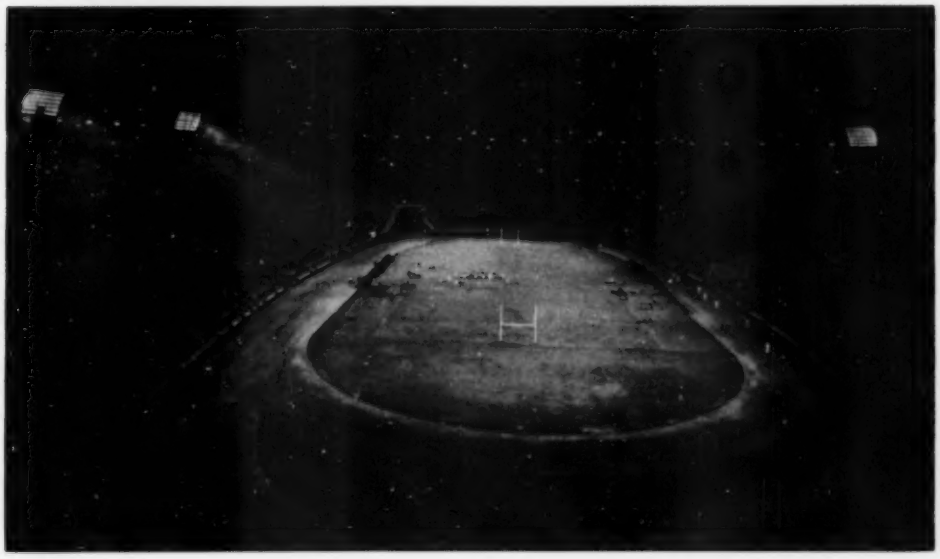
Control equipment is considered by theatrical people to be one of the most important phases of a theatre installation, but because of the cost too many stages are designed and installed without the dimmers, which are so necessary to transform a group of unimaginative lights into the core of a complete, adequate stage lighting installation. With higher building costs the amount of money available for the stage lighting has usually been restricted to such a point that it is impossible to give them adequate dimmer controls. Therefore, with this in mind, we have recently developed an additive type of dimmerboard. This is based on a basic frame which includes the cross connecting panel, a master switch and a number of "hot" circuits, and a number of tracks in the angle iron frame. Then according to the amount of money available a certain number of "dimmer drawers" can be originally purchased, and through the years as the budget allows extra dimmer drawers can be added as simply as sliding in a bureau drawer. An installation of this type has the advantages of following the basic master plan without the disadvantage of having the original total being so high as to cause the school board to throw the entire stage lighting out of the contract.

We are heartily in agreement with the establishing of a complete master plan with the emphasis on the complete installation of all the permanent facilities, and if necessary only the minimum of the portable equipment in the original installation.

Floodlighting a Stadium

Six floodlight towers, each with 72 floodlights, illuminate the playing area of the Los Angeles Coliseum. Each floodlight is equipped with a 1500-watt G-bulb service lamp. The towers are approximately 136 feet above the playing field and 300 feet back from the nearest sideline. Tower construction was designed to avoid the light from any one row of lamps being blocked by adjacent rows (see photo).

The area of the field which is illuminated can be adjusted for various seasonal activities. In the autumn, the stadium, which seats 101,670, is used for football; in the spring, for trackmeets and rodeos. Each floodlight has been accurately sighted on a point on the field, determined by aiming charts which were calculated to spread the light for the different activities. Both vertical and horizontal settings were marked on the indicating quadrant furnished with each floodlight. From these settings on each light, the illumination can be concentrated on the football playing area or spread out to include the entire track and area needed for other sports. Data and photo courtesy of R. H. Goodman, Crouse-Hinds Company, Syracuse, N. Y.



Appraisal of Modern Fluorescent Office Lighting Systems

By GEORGE J. TAYLOR

ILLUMINATION of offices to levels of 50 footcandles is a building management factor of some significance in recent years.

Space-hungry businesses throughout the land have created a minor boom in the erection of large buildings for office occupancy. At the same time, post-war building costs have placed the "economic height" of the new buildings at about twenty-five stories. Without the usually desirable light tower space, the owners must attract and hold tenants with such features as good artificial illumination and complete air-conditioning.

Nor are the new "baby skyscrapers" the only buildings seeking to offer the best recommended practices. Since office buildings, as a rule, are given a fifty-year life for tax purposes, many older buildings are being, or will be, modernized to keep pace with the modern buildings' bidding for tenant occupancy. Indeed, old-time operators of wide experience in the real estate business have indicated that older commercial structures, remodeled, are as good as, and often better than, new ones. Another factor in the present-day building program is manufacturing concerns in out-of-the-city rural districts. Here modern factory buildings are following the trend of large one-or-two-story adjacent office units.

High on the list of new building demands, and the modernization of old buildings, is the requirement of good office lighting.

Figure 1. — Typical multi-story structures like this are providing occupants with high levels of quality illumination in keeping with modern day practice.

Application of Recommended Practices

Adequate lighting requirements for offices have been well defined by the Illuminating Engineering Society. As mentioned, these requirements are more than ever appreciated, though perhaps not fully understood, by building owners and "specifiers" of lighting equipment. The factors involved in achieving these results — comfort, adequate illumination (50 footcandles for the more difficult tasks), and pleasing appearance — have not been so well delineated, however. Even less understood by most specifiers are the overall economics involved for an installation meeting recommended practice. For the most part they assume it is "expensive." Desirable, yes — but expensive. Good lighting can be "cheaper" than they think.

To aid such "specifiers," and for that matter illuminating engineers, in the selection of equipment for specific office application, a study has been made of eighteen currently available types of fluorescent luminaires commonly used for office lighting, analyzed from the standpoint of cost, comfort, and aesthetics. Since almost all luminaires are suitable in some circumstances, a method has been devised to determine under what circumstances any given type may be applicable.

Luminaire Types Analyzed

The comparative analysis of fluorescent luminaires is divided into two categories:

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Day-Brite Lighting, Inc., New York, N. Y.

(1) Ceiling mounted or suspended (below the ceiling)
(2) Troffer types, recessed (above the ceiling)

In the grouping of the below-ceiling type luminaires are (See Table I):

1. Metal sides with louvered bottom finished in baked white enamel
a. For two 40-watt T12 lamps (Types 1 and 9)
b. For two 75-watt T12 lamps (Type 2)

2. Diffusing glass or plastic sides with louvered bottom finished in baked white enamel
a. For two 40-watt T12 lamps (Types 5, 6, 7, and 8)
b. For four 40-watt T12 lamps (Types 3 and 4)

3. Luminous-indirect using plastic shield
a. For two 40-watt T12 lamps (Type 10)

In the grouping of the Troffers are the following (See Table I):

1. Louvered bottom — finished in baked white enamel
a. For two 40-watt T12 lamps (Type 14)
b. For three 40-watt T12 lamps (Type 11)
c. For two 75-watt T12 lamps (Type 15)

2. Ribbed glass bottom — reflecting surfaces finished in baked white enamel
a. For two 40-watt T12 lamps (Type 12)

3. Lens bottom (low brightness prismatic) — reflecting surfaces finished in baked white enamel
a. For two 40-watt T12 lamps (Type 13)

4. Parabolic Alzak aluminum
a. Louvered bottom for two 40-watt T12 lamps (Type 16)
b. Cross baffles for one 40-watt T12 lamp (Type 17)
c. Open type for one 40-watt T17 lamp (Type 18)

The types of luminaires included in the analysis are those frequently installed for office lighting, and currently in most demand for this application. The eighteen different lighting systems and luminaire types analyzed are shown in sketch form in Table I.

Room Conditions

In order to analyze each luminaire type in relation to the space in which it would be used, three office sizes were selected, as representing average conditions concerning room size.

Each having a 10-foot ceiling, the office sizes included in the analysis are:

1. Small ___ 20′ x 20′ or 400 square feet. Room Index—G
2. Medium _ 40′ x 60′ or 2400 square feet. Room Index—C
3. Large ___ 60′ x 120′ or 7200 square feet. Room Index—A

The small room size (20′ x 20′) is not considered to be a private office. It is assumed to be an area where difficult seeing tasks are performed by three or more employees. However, such a lighting arrangement would be quite suitable for private offices.

It is considered that room finishes as specified by the I.E.S. Recommended Practice of Office Lighting will be employed. Illumination calculations, using the lumen method, are based on a ceiling reflection factor of 75 per cent and walls at 50 per cent. Beyond this, furniture and machines, particularly working surfaces such as table and desk tops, typewriters, calculating machines, etc., should have reflectances of the order of 30 to 35 per cent. Floor coverings are assumed to be light in tone having a reflectance of 30 per cent. The tendency is toward even higher reflectance values than recommended providing greater comfort in so doing.

Employee comfort is considered important in office operations and acoustical treatment of ceilings to reduce the sound level is being widely used in modern offices. Consequently in the cost studies presented, two types of ceilings are considered: (1) suspended furred metal lath and plaster and (2) suspended furred metal acoustical ceilings. Regular acoustical type blocks may be included with the first type of ceiling, and cost of installing luminaires would be considered approximately the same as for plaster ceilings.

Metal acoustical ceilings have a slightly lower overall average reflection factor than plaster ceilings painted white. No change, however, is made in the illumination calculations because it is considered that the baked white enamel surfaces of the metal acoustical ceiling will be more serviceable than that of flat white paint on plaster ceilings. With regular acoustical blocks, those having the highest reflection values should be used, and are assumed in this analysis.

Lighting Calculations

Illumination computations were made for the 18 types of lighting systems, in the three room sizes, for the two ceiling conditions, using practical lighting layouts utilizing the best arrangement of luminaires that would provide as nearly as possible 50 footcandles. The conditions and general factors applying to these computations are shown in Table I. The table shows *general data* applying to the three room sizes listed as Series I, II, and III, for the two types of ceilings. An operating rate of 2000 hours per year was used in determining annual operating costs, with the power rate of 2½c per kwh.

Varying opinions have been expressed and published for lumen output and life of fluorescent lamps within recent months. Average values were used in the illumination calculations as follows:

Lamp	Type of Contact	3500K White Lumens	Average Life Hours
40w 48″ T12	Bi-pin	2400	7500
40w 60″ T17	Bi-pin	2400	6000
75w 96″ T12 430ma	Single pin	4800	6000

TABLE I.—Comparison of Office Lighting Systems — General Data.

Luminaire Classification		Suspended and Ceiling Mounted Luminaires										Recessed Troffer Luminaires							
Type of Luminaire		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
General Data	Type of Mounting	Suspension	Suspension	Ceiling	Suspension	Ceiling	Suspension	Ceiling	Suspension	Suspension	Suspension	Recessed	Recessed	Recessed	Recessed	Recessed	Recessed	Recessed	Recessed
	No. Lamps per Luminaire	2-40	2-75	4-40	4-40	2-40	2-40	2-40	2-40	2-40	2-40	2-40	2-40	2-40	2-40	2-75	2-40	2-40	1-40 T-17
	Luminaire Shielding	24° x 25°	24° x 25°	30° x 22°	30° x 22°	27° x 28°	21° x 26°	31° x 30°	37° x 28°	45° x 45°	Lens. Ind.	30° x 22°	Rib Glass	L. B. Lens	30° x 22°	30° x 22°	45° x 22°	45° x 22°	45° x 0°
	Approx. Luminaire Dimen.																		
	Depth (Inches)	6½	6½	6½	6½	6½	4	4	6½	5½	5	7	7	7	7	7	7	10½	10½
	Top Opening (Inches)	10	10	16	16	12	12	—	12	5½	10½	—	—	—	—	—	—	—	—
	Bottom Opening (Inches)	12½	12½	12½	12½	9½	12½	12½	9½	12	—	9½	9½	10½	9½	9½	10½	10½	10½
	Louver Depth (Inches)	1½	1½	2	2	2½	1½	1½	2½	2	—	2	—	—	2	2	2½	6½	—
	Aver. Brightness at 45°																		
	Crosswise (Cp/Sq In.)	0.6	0.6	2.7	2.6	1.0	1.1	1.6	0.9	0.8	0.2	2.3	1.0	1.2	1.5	1.5	0.2	0.6	0.1
	Lengthwise (Cp/Sq In.)	0.6	0.6	2.4	2.3	0.8	1.4	1.6	0.7	0.8	0.2	2.2	1.0	1.7	1.3	1.5	1.5	0.6	1.5
	Maintenance Factor	.75	.75	.75	.75	.75	.70	.70	.75	.75	.60	.70	.70	.70	.70	.70	.70	.70	.70
	Watts per Luminaire	95.5	170	191	191	95.5	95.5	95.5	95.5	95.5	95.5	145	95.5	95.5	95.5	170	95.5	47.75	54
	Replacement Cost per Lamp	25¢	25¢	30¢	25¢	30¢	25¢	30¢	25¢	25¢	25¢	30¢	30¢	30¢	30¢	30¢	30¢	30¢	25¢
	Cleaning Cost per Luminaire	50¢	$1.00	75¢	75¢	50¢	50¢	50¢	50¢	60¢	50¢	50¢	50¢	50¢	50¢	$1.00	50¢	50¢	50¢
	Cleaning Cycle — Months	12	12	12	12	12	9.6	9.6	12	12	6.85	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
	No. Cleanings per Year	1	1	1	1	1	1½	1½	1	1	1⅞	1½	1½	1½	1½	1½	1¼	1¼	1¼
Series I Plaster Ceiling and Metal Acoustical Ceiling Room Size—20' x 20'	Coefficient of Utilization	.44	.44	.40	.42	.40	.43	.41	.40	.30	.25	.37	.44	.40	.40	.40	.39	.40	.32
	No. of Luminaires	12	6	7	7	14	14	14	14	15	20	11	14	12	15	7	15	25	24
	Total Kilowatts	1.147	1.020	1.337	1.337	1.337	1.337	1.337	1.337	1.432	2.674	1.594	1.337	1.147	1.433	1.190	1.432	1.194	1.297
	Watts per Sq. Ft.	2.87	2.55	3.34	3.34	3.34	3.34	3.34	3.34	3.58	6.69	3.99	3.34	2.87	3.58	2.98	3.58	2.99	3.24
	Footcandles — Calculated	47.5	47.5	50.3	50.0	50.3	50.6	48.2	50.3	51.2	50.4	51.2	51.7	48.2	50.3	47.0	49.1	51.4	52.4
Series II Plaster Ceiling and Metal Acoustical Ceiling Room Size—40' x 60'	Coefficient of Utilization	.57	.57	.49	.52	.50	.56	.52	.51	.47	.36	.43	.52	.50	.49	.49	.46	.50	.41
	No. of Luminaires	60	30	34	32	70	64	70	65	70	117	56	70	62	72	35	70	120	120
	Total Kilowatts	5.730	5.100	6.494	6.112	6.685	6.112	6.685	6.206	6.685	11.174	8.120	6.685	5.921	6.876	5.950	7.449	5.730	6.480
	Watts per Sq. Ft.	2.39	2.13	2.71	2.55	2.79	2.55	2.79	2.59	2.79	4.66	3.38	2.79	2.47	2.87	2.48	3.10	2.39	2.70
	Footcandles — Calculated	51.8	51.3	49.9	49.9	52.5	50.2	50.9	49.7	49.3	50.5	50.5	51.0	50.3	49.4	48.0	50.2	46.7	51.2
Series III Plaster Ceiling and Metal Acoustical Ceiling Room Size—60' x 120'	Coefficient of Utilization	61	61	.52	.55	58	61	.56	.55	.50	.42	45	.54	.50	.51	.51	.47	.50	.43
	No. of Luminaires	168	84	98	91	196	175	192	182	203	297	162	196	162	210	105	222	364	345
	Total Kilowatts	16.044	14.280	18.716	17.381	17.761	16.731	18.326	17.381	19.287	29.364	23.490	18.716	17.381	20.055	17.850	22.136	17.361	18.630
	Watts per Sq. Ft.	2.23	1.98	2.60	2.41	2.47	2.32	2.55	2.41	2.69	3.92	3.26	2.60	2.41	2.79	2.48	3.08	2.41	2.59
	Footcandles — Calculated	51.2	51.2	50.9	50.0	49.3	49.6	50.2	50.0	50.5	49.9	51.0	49.4	50.2	50.0	50.0	50.0	50.2	49.6

Average Lamp Lumens { 40-W 48" T-12 — 3400 Lumens; 40-W 60" T-17 — 3400 Lumens; 75-W 96" T-12 — 4600 Lumens.

Average Lamp Life { 40-W 48" T-12 — 7500 Hours; 40-W 60" T-17 — 6000 Hours; 75-W 96" T-12 — 6000 Hours.

Luminaire Shielding *First Figure* Denotes Crosswise Shielding. *Second Figure* Denotes Lengthwise Shielding

TABLE II.—Comparison of Office Lighting Systems — Cost Data.

Type of Luminaire (See Table I)			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Series I Plaster Ceiling and Metal Acoustical Ceiling — Room Size 20′ x 20′ — Annual Operation 2000 Hours	General Costs	Building Wiring	$75.00	75.00	85.00	85.00	80.00	80.00	80.00	80.00	75.00	95.00	75.00	80.00	80.00	75.00	85.00	75.00	85.00	90.00
		Luminaires (Less Lamps)	$224.25	249.75	241.50	259.50	280.00	306.00	297.00	311.50	492.90	1,131.27	267.85	363.00	380.25	297.80	411.20	468.95	572.50	630.00
		Original Lamps	$19.30	21.44	22.52	22.52	22.52	22.52	22.52	22.52	24.12	45.04	26.52	22.52	19.30	24.12	36.68	24.12	20.20	44.40
		Mounting Luminaires (P)	$39.00	39.00	44.15	57.25	67.40	61.50	67.75	69.50	64.50	120.25	95.55	134.89	108.00	180.25	108.50	139.25	217.25	209.70
		Mounting Luminaires (M)	$42.15	42.15	48.35	61.45	53.70	65.70	51.95	66.89	70.89	133.00	54.25	82.30	63.00	74.05	56.00	74.05	122.45	119.70
	Annual Operating Costs	Renewal Lamps	$6.15	10.48	6.01	6.01	6.01	6.01	6.01	6.01	6.44	12.02	7.08	6.01	5.15	6.44	12.21	6.44	5.37	14.76
		Lamp Replacement	$1.60	1.60	2.24	1.87	2.24	1.87	2.24	1.87	2.00	3.74	2.64	2.24	1.92	2.40	1.40	2.40	2.00	2.00
		Cleaning	$6.00	6.00	5.25	5.25	7.00	8.75	8.75	7.00	9.00	24.50	6.88	8.75	7.50	9.28	8.75	9.28	15.63	15.00
		Energy @ 2½¢/kwh	$57.35	51.00	66.85	66.85	66.85	66.85	66.85	66.85	71.60	133.70	79.70	66.85	57.35	71.60	59.50	71.60	89.70	64.85
		Amortization (P)	$56.37	59.94	61.98	66.64	67.10	73.13	69.71	73.80	100.49	200.11	86.39	92.76	91.24	86.10	97.39	108.46	137.89	146.31
		Amortization (M)	$56.94	59.32	62.61	67.37	66.06	73.71	70.34	74.75	101.44	211.62	74.44	77.52	78.28	80.08	81.91	90.10	111.79	110.06
	Total Costs	First Cost (Incl. Lamps) (P)	$357.55	386.19	393.17	424.27	429.92	470.02	447.27	474.52	656.52	1,391.56	564.92	680.92	587.55	627.27	643.38	696.32	894.95	974.10
		Annual Operating Cost (P)	$126.47	127.32	142.33	146.62	149.20	156.61	153.56	155.53	189.53	383.07	182.69	176.61	163.16	185.92	179.25	196.28	230.29	242.84
		First Cost (Incl. Lamps) (M)	$360.70	389.34	397.37	428.47	436.22	474.23	451.67	480.82	662.82	1,404.31	485.27	499.32	501.15	520.42	540.18	587.77	722.90	786.69
		Annual Operating Cost (M)	$126.94	127.80	142.96	147.35	150.16	157.19	154.19	156.48	189.48	394.88	170.74	161.37	159.20	169.90	163.77	180.00	194.40	214.71
		Footcandles — Calculated	47.5	47.5	50.3	52.8	50.3	50.6	48.2	50.3	51.2	50.4	51.2	51.7	48.3	50.3	47.0	49.1	51.4	52.4
Series II Plaster Ceiling and Metal Acoustical Ceiling — Room Size 40′ x 40′ — Annual Operation 2000 Hours	General Costs	Building Wiring	$423.00	423.00	418.00	408.00	423.00	423.00	423.00	423.00	423.00	483.00	408.00	423.00	423.00	423.00	423.00	438.00	468.00	498.00
		Luminaires (Less Lamps)	$1,163.75	1,186.25	1,172.00	1,166.00	1,400.00	1,396.75	1,478.75	1,422.50	2,220.30	3,796.42	1,951.60	1,780.50	1,946.44	1,806.84	2,019.00	2,410.02	2,684.96	3,111.70
		Original Lamps	$96.48	157.20	109.34	102.91	112.56	102.91	112.56	104.52	112.56	188.14	135.07	112.56	99.70	115.78	183.40	125.42	98.48	222.00
		Mounting Luminaires (P)	$192.50	192.50	211.75	260.00	231.88	265.25	224.38	277.50	298.75	499.50	486.50	673.75	559.25	625.50	542.50	677.63	1,042.50	1,048.50
		Mounting Luminaires (M)	$204.75	204.75	228.55	276.80	259.38	278.20	238.38	302.00	325.00	543.60	274.50	411.25	625.25	355.50	260.00	385.13	592.50	596.50
	Annual Operating Costs	Renewal Lamps	$25.76	52.35	29.18	27.48	30.05	27.48	30.05	27.91	30.05	50.23	36.07	30.05	26.62	30.91	61.07	33.49	25.76	73.93
		Lamp Replacement	$6.01	5.00	10.89	8.55	11.21	8.55	11.21	8.68	9.35	15.62	13.66	11.21	9.81	11.54	6.99	12.50	9.61	9.99
		Cleaning	$60.00	30.00	25.50	24.00	35.00	40.00	43.75	32.50	42.00	102.38	35.00	43.75	38.75	45.00	43.75	48.75	75.00	75.00
		Energy @ 2½¢/kwh	$286.50	255.00	324.70	395.60	394.25	395.60	334.25	330.40	534.25	956.70	666.60	394.85	294.05	343.80	297.50	372.45	288.50	294.00
		Amortization (P)	$289.62	301.99	301.76	309.00	339.96	335.46	350.65	350.18	474.57	663.10	442.52	464.67	471.03	473.51	479.41	561.70	664.42	736.00
		Amortization (M)	$291.46	293.83	304.28	311.52	344.09	337.42	352.75	353.86	478.51	669.71	394.08	391.62	405.96	398.03	406.81	479.19	545.30	660.45
	Total Costs	First Cost (Incl. Lamps) (P)	$1,815.73	1,958.95	1,932.09	1,958.91	2,167.44	2,127.91	2,238.69	2,227.52	3,064.81	4,367.26	2,881.17	2,998.81	3,029.39	3,061.12	3,167.90	3,651.07	4,291.94	4,680.20
		Annual Operating Cost (P)	$639.89	644.34	692.04	674.63	750.67	737.11	760.91	729.67	990.23	1,890.03	933.05	893.91	842.38	904.78	888.72	1,028.89	1,061.29	1,219.00
		First Cost (Incl. Lamps) (M)	$1,827.96	1,971.20	1,928.89	1,975.71	2,194.94	2,140.86	2,252.69	2,252.02	3,091.06	4,411.36	2,491.57	2,511.81	2,594.55	2,557.78	2,643.90	3,101.65	3,497.79	3,976.00
		Annual Operating Cost (M)	$641.73	646.19	694.56	677.15	754.80	719.05	772.01	733.35	994.16	1,396.64	974.61	810.88	777.31	829.28	816.12	946.38	942.17	1,083.37
		Footcandles — Calculated	51.3	51.3	49.9	49.9	52.5	50.2	50.9	49.7	49.3	50.5	50.5	51.0	50.3	49.4	48.0	50.2	49.7	51.2
Series III Plaster Ceiling and Metal Acoustical Ceiling — Room Size 60′ x 120′ — Annual Operation 2000 Hours	General Costs	Building Wiring	$1,182.00	1,182.00	1,232.00	1,427.00	1,182.00	1,182.00	1,182.00	1,182.00	1,182.00	1,338.00	1,152.00	1,182.00	1,182.00	1,182.00	1,182.00	1,212.50	1,362.00	1,422.00
		Luminaires (Less Lamps)	$3,115.00	3,366.00	3,391.00	3,640.00	3,720.00	3,678.50	4,056.50	4,350.50	6,645.17	7,733.33	5,377.86	5,002.69	5,710.18	5,514.29	6,046.74	7,159.72	8,075.86	8,993.85
		Original Lamps	$270.34	440.16	315.17	292.66	299.09	281.60	308.74	292.66	326.42	477.56	380.74	315.17	292.66	337.68	550.20	373.06	292.66	638.25
		Mounting Luminaires (P)	$546.50	542.50	613.25	750.75	620.38	754.25	626.50	778.75	864.50	1,265.00	1,407.38	1,886.50	1,638.13	1,824.38	1,627.50	2,014.50	3,162.25	3,014.63
		Mounting Luminaires (M)	$581.70	581.70	666.65	834.55	691.33	783.45	664.65	849.70	938.00	1,372.80	799.88	1,151.50	955.25	1,036.88	940.00	1,144.50	1,797.25	1,720.88
	Annual Operating Costs	Renewal Lamps	$72.31	146.56	84.15	78.34	79.85	75.13	82.43	78.14	87.15	127.51	104.33	84.15	78.14	90.16	183.22	99.61	78.14	212.55
		Lamp Replacement	$22.43	13.99	31.40	24.30	29.80	23.36	30.76	24.30	27.10	39.65	38.53	31.40	29.16	33.64	20.98	37.17	29.16	28.72
		Cleaning	$84.00	84.00	73.50	68.25	92.00	109.38	120.00	91.00	121.80	259.88	101.25	122.50	113.75	131.25	131.25	145.00	227.50	215.63
		Energy @ 2½¢/kwh	$802.20	714.00	935.80	869.05	880.15	835.65	956.60	860.05	960.35	1,416.20	1,176.50	935.80	869.05	1,002.75	892.50	1,107.80	869.05	931.50
		Amortization (P)	$914.42	940.23	976.34	979.09	917.01	920.60	969.70	1,033.34	1,392.40	1,650.80	1,276.99	1,299.33	1,368.20	1,366.77	1,417.09	1,647.40	1,992.17	2,121.22
		Amortization (M)	$920.46	955.11	984.35	989.26	927.65	930.74	974.46	1,043.90	1,402.43	1,666.97	1,166.16	1,095.98	1,176.15	1,149.13	1,230.71	1,404.20	1,534.60	1,725.46
	Total Costs	First Cost (Incl. Lamps) (P)	$5,103.84	5,510.66	5,541.42	6,110.41	5,821.67	5,896.15	6,175.74	6,603.91	9,014.09	10,812.91	8,327.96	8,266.26	8,832.97	8,856.65	9,406.64	10,750.29	12,892.77	14,086.73
		Annual Operating Cost (P)	$1,795.19	1,807.73	2,001.29	2,019.43	2,007.61	1,974.36	2,110.09	2,097.82	2,507.80	3,494.04	2,696.00	2,473.28	2,454.30	2,634.57	2,645.04	3,007.05	3,196.02	3,569.62
		First Cost (Incl. Lamps) (M)	$5,146.94	5,540.86	5,594.82	6,174.21	5,892.42	5,925.35	6,213.69	6,674.86	9,091.59	10,921.71	7,189.12	7,030.67	7,554.01	7,407.56	7,963.95	9,139.36	10,507.66	11,497.13
		Annual Operating Cost (M)	$1,801.22	1,813.64	2,009.30	2,029.00	2,016.45	1,980.26	2,124.41	2,108.47	2,508.53	3,512.21	2,525.17	2,269.93	2,264.25	2,406.93	2,423.65	2,793.79	2,830.25	3,122.68
		Footcandles — Calculated	51.2	51.2	50.9	50.0	49.3	49.6	50.2	50.0	50.5	49.9	51.0	49.4	50.2	50.0	50.0	50.8	50.2	49.8

(P) Suspended *Plaster* Ceiling.
(M) Suspended *Metal Acoustical* Ceiling

The lamp life of the 75-watt 96" T12 (slimline) is based on using the series type ballast suitable for operating this lamp.

Cost Data

The *general costs* and *annual operating costs* for the three "Series" of conditions are tabulated in Table II. The *types of luminaires* shown by numerical numbers in this table apply to the same numbers shown in Table I. The computed costs are, as previously mentioned, based upon practical lighting layouts of luminaires to produce as nearly as possible 50 footcandles.

Branch circuit wiring costs are included in the comparative analysis as a part of the cost of the various lighting systems. This will aid in approximating the average cost of rewiring old buildings where necessary to provide modern illumination of recommended levels. Table II shows this as *building wiring cost* and includes the cost and installation of lighting panel boards, branch circuit wiring in conduit, ceiling outlets and local switches.

Office building structures vary in the modules selected for best and most efficient construction and utilization of space. A good average module is 20′ x 20′ and this was chosen in determining the room sizes used in this comparative analysis of lighting systems. It is further considered that the Series I (20′ x 20′) are permanent structures enclosed by solid walls. In these small offices are included four ceiling outlets and two switches. Larger office areas, Series II (40′ x 60′) and Series III (60′ x 120′) allows for sufficient ceiling and switch outlets for flexibility of control. Therefore, at least one switch is provided for every 20′ x 20′ module, allowing for changes in partitions at any time. Where large blocks of fluorescent lighting can be controlled by single switches, without due respect to possible flexibility in partitioning, substantial savings can be effected in wiring costs by reducing the number of ceiling outlets and switches.

The *mounting cost* includes cost and installation of mounting anchorage points in the ceiling from which luminaires and suspension members are supported. It includes the cost of wire used and labor in making connections from luminaires to the branch circuit outlets and the mounting or installation of luminaires in their proper locations. These costs and the cost of luminaires are based upon normal competitive bidding for large buildings through union electrical contractor purchasing materials and equipment through an authorized electrical distributor.

The net cost of fluorescent lamps is based upon a 30 per cent discount from list prices to which is added an amount of 10.4 per cent of list prices for excise tax. Amortization is shown as 15 per cent of total luminaire costs (excluding lamps). The useful life for building wiring was taken as double that of the luminaires and therefore amortization for this item is given as 7½ per cent.

Direct Comparative Costs

In arriving at final cost comparisons, Table III was prepared. Where lighting layouts did not pro-

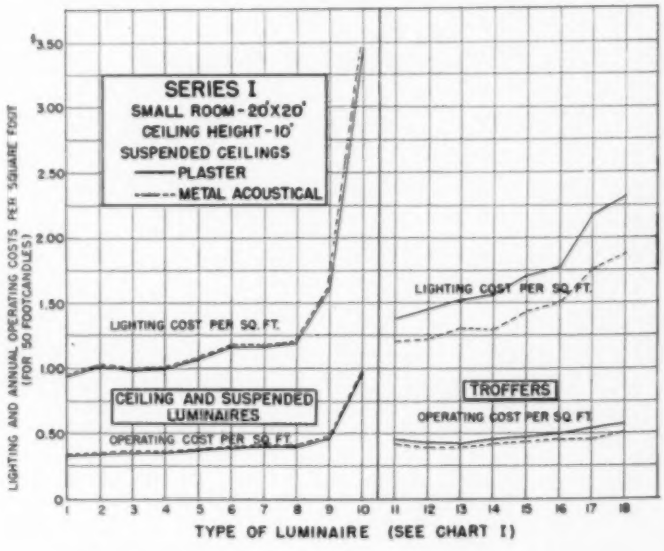


Figure 2. Average costs per square foot for typical office type luminaires to produce 50 footcandles. Lighting cost includes local panel boards and wiring to luminaires.

TABLE III.—Comparison of Office Lighting Systems — Adjusted to 50 Footcandles from Table II.

Luminaire Classification		Suspended and Ceiling Mounted Luminaires										Recessed Troffer Luminaires							
Type of Luminaire (See Table I)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Series I Plaster Ceiling **Room Size 20' x 20'**	Total First Cost (Incl. Lamps)	$376.36	$96.30	$99.61	$01.70	$37.34	$64.30	$63.95	$71.67	$81.42	$1,300.62	$51.93	$61.00	$09.11	$23.51	$04.43	$00.85	$69.09	$99.29
	Percent (of Type 1)	100%	106.0%	103.8%	106.8%	113.6%	123.4%	123.3%	125.3%	170.4%	346.9%	140.7%	154.4%	161.6%	165.7%	181.9%	189.3%	231.1%	246.9%
	Total Operating Cost	$133.13	$34.03	$41.46	$39.85	$46.30	$54.73	$50.29	$54.80	$65.17	$60.01	$70.49	$70.76	$69.67	$04.00	$90.09	$90.81	$34.13	$31.67
	Percent (of Type 1)	100%	100.7%	$06.3%	$04.3%	$11.4%	$36.2%	$19.7%	$16.1%	$36.0%	$55.5%	$36.1%	$30.3%	$30.9%	$30.0%	$43.9%	$50.1%	$60.9%	$74.0%
	First Cost per Sq. Ft.	$0.94	1.02	0.80	1.00	1.07	1.16	1.16	1.16	1.00	3.45	1.30	1.45	1.53	1.56	1.71	1.77	2.17	2.32
	Operating Cost per Sq. Ft.	$0.30	0.34	0.35	0.35	0.37	0.39	0.40	0.39	0.46	0.53	0.45	0.43	0.42	0.46	0.48	0.50	0.54	0.56
Series I Metal Acoustical Ceiling **Room Size 20' x 20'**	Total First Cost (Incl. Lamps)	$373.67	$09.32	$34.59	$05.76	$53.60	$60.53	$60.31	$77.94	$47.36	$1,301.00	$74.11	$02.04	$16.69	$17.39	$74.75	$30.35	$03.06	$30.40
	Percent (of Type 1)	100%	107.9%	104.0%	106.9%	114.2%	123.6%	123.4%	125.9%	170.6%	366.9%	124.9%	127.3%	130.6%	130.2%	161.4%	157.6%	195.1%	197.7%
	Total Operating Cost	$133.63	$34.32	$42.10	$39.45	$49.26	$55.30	$50.94	$55.54	$66.10	$61.90	$66.81	$56.04	$55.46	$69.80	$74.35	$69.34	$80.04	$84.83
	Percent (of Type 1)	100%	100.7%	106.6%	104.4%	111.7%	116.2%	119.7%	116.4%	136.2%	205.9%	124.0%	116.9%	116.3%	130.4%	130.4%	187.1%	141.5%	153.2%
	First Cost per Sq. Ft.	$0.95	1.02	0.99	1.01	1.06	1.17	1.17	1.19	1.62	3.40	1.19	1.21	1.30	1.39	1.44	1.80	1.76	1.98
	Operating Cost per Sq. Ft.	$0.33	0.34	0.36	0.35	0.37	0.39	0.40	0.39	0.46	0.95	0.42	0.39	0.39	0.42	0.44	0.46	0.47	0.51
Series II Plaster Ceiling **Room Size 40' x 60'**	Total First Cost (Incl. Lamps)	$1,770.34	1,808.86	1,915.91	1,902.83	2,063.40	2,119.40	2,194.39	2,240.09	3,198.33	4,253.50	2,832.26	2,940.03	3,010.22	3,099.16	3,300.95	3,436.47	4,407.62	4,767.96
	Percent (of Type 1)	100%	107.9%	108.2%	110.9%	116.6%	119.7%	124.3%	126.6%	175.9%	244.2%	161.1%	166.1%	170.0%	175.0%	186.5%	200.4%	249.0%	269.3%
	Total Operating Cost	$633.69	638.33	692.43	675.50	734.43	714.34	756.05	754.05	902.05	1,376.13	923.72	866.60	857.33	915.73	926.05	1,024.77	1,089.94	1,190.96
	Percent (of Type 1)	100%	100.7%	111.1%	106.4%	116.5%	114.5%	121.2%	117.7%	143.6%	220.6%	146.1%	136.9%	134.2%	146.8%	146.8%	164.3%	174.7%	190.9%
	First Cost per Sq. Ft.	$0.74	0.80	0.80	0.82	0.86	0.89	0.92	0.93	1.30	1.80	1.19	1.23	1.25	1.29	1.38	1.43	1.84	1.99
	Operating Cost per Sq. Ft.	$0.26	0.26	0.29	0.28	0.30	0.30	0.32	0.31	0.37	0.57	0.38	0.36	0.35	0.38	0.39	0.43	0.45	0.50
Series II Metal Acoustical Ceiling **Room Size 40' x 60'**	Total First Cost (Incl. Lamps)	$1,702.38	1,821.92	1,932.75	1,979.66	2,089.50	2,132.30	2,212.14	2,260.53	3,134.93	4,367.25	2,666.65	2,662.56	2,572.90	2,580.73	2,796.62	3,080.65	3,892.22	3,984.55
	Percent (of Type 1)	100%	107.0%	108.4%	111.1%	117.2%	119.6%	124.1%	127.1%	175.9%	245.0%	130.4%	130.1%	144.7%	145.3%	156.9%	172.3%	201.0%	218.0%
	Total Operating Cost	$625.69	630.03	695.95	678.50	716.38	716.17	756.11	737.75	906.60	1,302.67	865.06	794.99	772.65	839.31	850.40	942.60	967.61	1,056.45
	Percent (of Type 1)	100%	100.7%	111.2%	108.4%	114.6%	114.5%	121.2%	117.9%	143.0%	221.0%	138.4%	127.1%	123.5%	134.1%	135.9%	150.7%	154.7%	169.2%
	First Cost per Sq. Ft.	$0.74	0.80	0.81	0.82	0.87	0.89	0.92	0.94	1.31	1.82	1.03	1.03	1.07	1.08	1.17	1.29	1.30	1.67
	Operating Cost per Sq. Ft.	$0.26	0.27	0.29	0.28	0.30	0.30	0.32	0.31	0.37	0.54	0.36	0.33	0.32	0.35	0.35	0.39	0.40	0.44
Series III Plaster Ceiling **Room Size 60' x 120'**	Total First Cost (Incl. Lamps)	$4,991.14	5,363.91	5,441.67	6,130.41	5,904.13	5,919.73	6,151.04	6,403.91	8,927.91	10,635.54	6,164.75	6,467.83	6,707.66	6,858.45	9,406.44	10,570.28	12,041.30	14,125.60
	Percent (of Type 1)	100%	107.9%	109.0%	122.4%	118.9%	118.6%	123.2%	132.9%	178.9%	217.1%	163.6%	170.1%	176.1%	177.5%	198.5%	211.9%	257.3%	283.0%
	Total Operating Cost	$1,753.90	1,766.20	1,966.27	2,019.43	2,036.32	1,982.28	2,110.22	2,097.83	2,571.82	3,503.01	2,643.16	2,503.21	2,448.47	2,634.57	2,645.04	2,988.47	3,183.24	3,523.66
	Percent (of Type 1)	100%	100.7%	112.1%	115.1%	116.1%	113.0%	120.3%	119.6%	145.5%	199.7%	150.7%	142.7%	139.6%	149.6%	150.8%	170.4%	181.5%	200.9%
	First Cost per Sq. Ft.	$0.69	0.75	0.76	0.85	0.82	0.82	0.85	0.92	1.24	1.50	1.12	1.19	1.22	1.23	1.31	1.47	1.70	1.96
	Operating Cost per Sq. Ft.	$0.24	0.25	0.27	0.28	0.28	0.28	0.29	0.29	0.35	0.49	0.37	0.35	0.34	0.36	0.37	0.42	0.44	0.49
Series III Metal Acoustical Ceiling **Room Size 60' x 120'**	Total First Cost (Incl. Lamps)	$5,030.42	5,462.31	5,494.11	6,174.21	5,976.69	5,959.09	6,199.03	6,474.86	9,000.07	10,943.55	7,046.21	7,115.74	7,505.79	7,607.56	7,963.95	6,902.81	10,465.63	11,543.12
	Percent (of Type 1)	100%	107.0%	109.2%	122.7%	118.9%	118.5%	123.9%	132.7%	178.9%	217.6%	140.1%	141.5%	149.6%	147.3%	158.3%	178.6%	208.1%	229.5%
	Total Operating Cost	$1,730.79	1,771.96	1,972.13	2,020.00	2,047.11	1,996.10	2,115.81	2,103.47	2,582.74	3,519.23	2,675.66	2,597.40	2,250.10	2,636.93	2,650.60	2,749.06	2,658.90	3,138.52
	Percent (of Type 1)	100%	100.7%	112.1%	115.2%	116.9%	113.0%	120.2%	119.0%	146.6%	200.0%	140.7%	130.6%	128.4%	136.6%	138.0%	156.2%	160.6%	178.2%
	First Cost per Sq. Ft.	$0.70	0.75	0.76	0.86	0.83	0.83	0.86	0.91	1.25	1.53	0.98	0.99	1.05	1.06	1.11	1.25	1.45	1.60
	Operating Cost per Sq. Ft.	$0.24	0.25	0.27	0.28	0.28	0.28	0.29	0.29	0.36	0.49	0.34	0.32	0.31	0.33	0.34	0.38	0.39	0.44

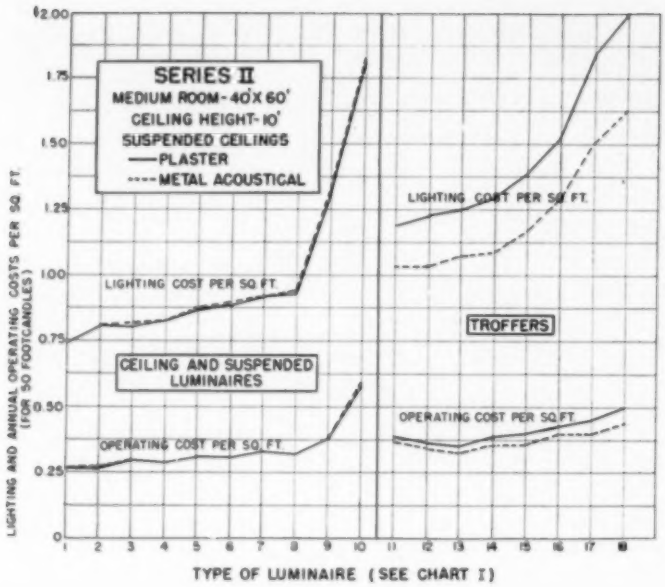

SERIES II
MEDIUM ROOM - 40'X 60'
CEILING HEIGHT - 10'
SUSPENDED CEILINGS
—PLASTER
----METAL ACOUSTICAL
LIGHTING COST PER SQ FT.
OPERATING COST PER SQ FT.
CEILING AND SUSPENDED LUMINAIRES
TROFFERS
LIGHTING AND ANNUAL OPERATING COSTS PER SQ FT. (FOR 50 FOOTCANDLES)
TYPE OF LUMINAIRE (SEE CHART I)

Figure 3. Average costs per square foot for typical office type luminaires to produce 50 footcandles. Lighting cost includes local panel boards and wiring to luminaires.

vide exactly 50 footcandles, proper adjustments were made to accomplish this result from Table II and recorded in Table III. Therefore, in this latter table, all cost comparisons are based on the same level of illumination so that direct comparisons can be made on an equal basis of equal footcandles.

Percentage values are given in Table III for quick comparison between the lighting systems shown. The values for the various systems are taken as a percentage of lighting system No. 1 in each case of the series tabulated.

Also included in Table III are the *costs per*

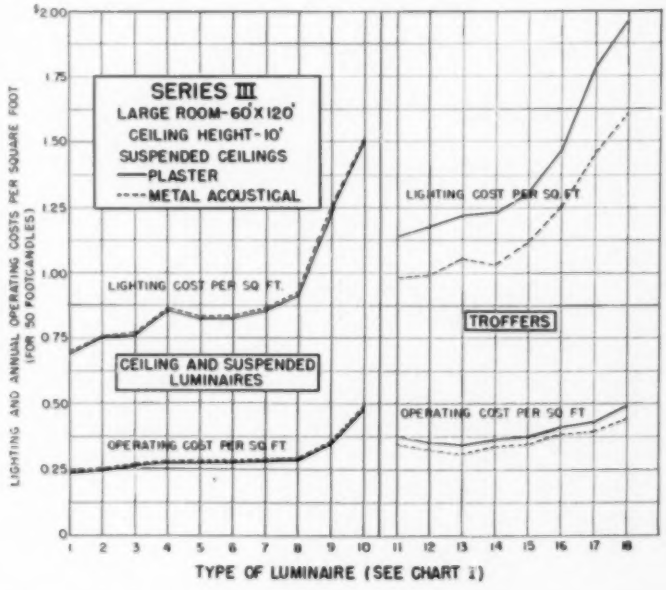
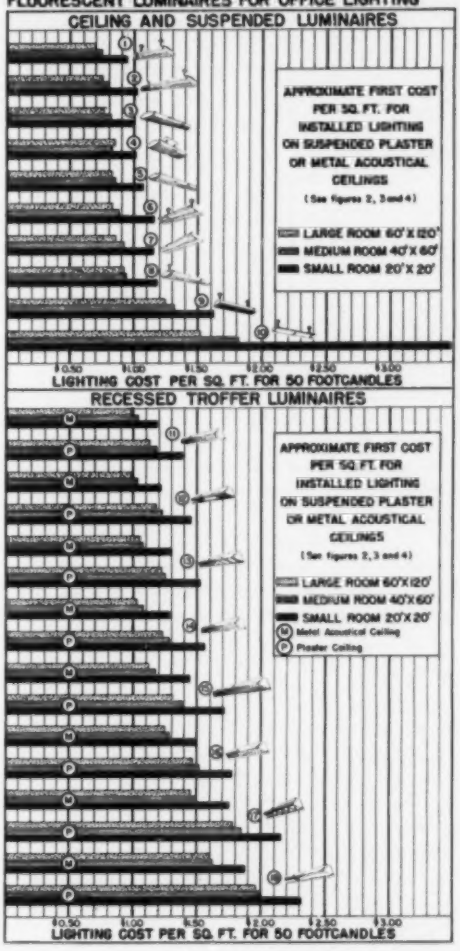

SERIES III
LARGE ROOM - 60'X 120'
CEILING HEIGHT - 10'
SUSPENDED CEILINGS
—PLASTER
----METAL ACOUSTICAL
LIGHTING COST PER SQ FT.
OPERATING COST PER SQ FT.
CEILING AND SUSPENDED LUMINAIRES
TROFFERS
LIGHTING AND ANNUAL OPERATING COSTS PER SQUARE FOOT (FOR 50 FOOTCANDLES)
TYPE OF LUMINAIRE (SEE CHART I)

Figure 4. Average costs per square foot for typical office type luminaires to produce 50 footcandles. Lighting cost includes local panel boards and wiring to luminaires.

square foot of all lighting systems in the three series, which many architects and engineers find useful in their building estimates. These values are plotted in Figs. 2, 3, and 4, together with *operating costs* per square foot which graphically show increasing costs of the various lighting systems analyzed.

For instance, referring to Fig. 3, a medium size room of 40′ x 60′, it is noted that the installed costs of lighting systems studied varies from about 74c to $1.80 per square foot for luminaires mounted below the ceiling, including wiring. Troffers vary from about $1.19 to $2.00 per square foot in plaster ceilings, and $1.03 to $1.62 per square foot in metal acoustical ceilings using T-Bar construction. Similar cost figures are plotted for small and large sized rooms in Fig. 2 (small room) and Fig. 4 (large room). In these graphs, it is noted that installation costs decrease as room sizes increase, which is a normal tendency. Sharp decreases in these costs are observed with luminous-indirect lighting (System 10), as room sizes increase. This is due to the fact that illumination levels are obtained almost entirely from the light reflected from the ceiling, and as room sizes increase the utilization of light increases markedly. For instance, taking the utilization as 100 per cent for a large room, the values become about 86 per cent for a medium room and 60 per cent for a small room. For a typical Troffer installation (System 16) where all light is directed downward, these values become 100 per cent, 98 per cent and 83 per cent respectively.

CHART I - COST COMPARISON OF TYPICAL TYPE FLUORESCENT LUMINAIRES FOR OFFICE LIGHTING


CEILING AND SUSPENDED LUMINAIRES
APPROXIMATE FIRST COST PER SQ. FT. FOR INSTALLED LIGHTING ON SUSPENDED PLASTER OR METAL ACOUSTICAL CEILINGS
(See figures 2, 3 and 4)
LARGE ROOM 60′X 120′
MEDIUM ROOM 40′X 60′
SMALL ROOM 20′X 20′
$0.50 $1.00 $1.50 $2.00 $2.50 $3.00
LIGHTING COST PER SQ. FT. FOR 50 FOOTCANDLES
RECESSED TROFFER LUMINAIRES
APPROXIMATE FIRST COST PER SQ. FT. FOR INSTALLED LIGHTING ON SUSPENDED PLASTER OR METAL ACOUSTICAL CEILINGS
(See figures 2, 3 and 4)
LARGE ROOM 60′X 120′
MEDIUM ROOM 40′X 60′
SMALL ROOM 20′X 20′
(M) Metal Acoustical Ceiling
(P) Plaster Ceiling
$0.50 $1.00 $1.50 $2.00 $2.50 $3.00
LIGHTING COST PER SQ. FT. FOR 50 FOOTCANDLES

Appraisal of Lighting Systems

Comparisons of first costs for the 18 types of luminaires analyzed, for the three sizes of rooms, and two types of ceilings, are shown in Chart I. However, the *first cost* and *operating cost* of a lighting system is by no means the criterion upon which a lighting installation is selected. Other important factors beside cost may be the determining factor in the final selection of the system to use. These factors, not necessarily in the order of their importance, may be listed as follows:

1. Comfort — quality of illumination
2. Appearance — aesthetic effect
3. Maintenance — lasting qualities
4. First cost — initial investment
5. Operating cost — annual investment

Whatever weight or importance is assigned to any of the above factors for any valid or special reason will determine the type of lighting system to use. If the ultimate in comfort is desired, System 10 might be considered. Should greatest emphasis be given to appearance, System 13 may be desired. If low maintenance costs are a criterion, System 4 may be the selection. If cost is a consideration, System 1 will provide good all-around utilitarian lighting. The point is, the five factors listed above do have a direct bearing on the final selection of a lighting system.

Table IV presents a "rating chart" for the 18 lighting systems analyzed, each rating based upon the relative merits of the respective systems. The ratings assume the following:

A — Excellent
B — Good
C — Fair
D — Poor

TABLE IV.—Rating Classification for Office Lighting Systems.

Luminaire Classification		Suspended and Ceiling Mounted Luminaires										Recessed Troffer Luminaires								
Type of Luminaire		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Appearance		C	C	B	C	B	B	A	C	C	D	C	B	B	A	B	B	C	D
Maintenance		A	A	A	A	A	B	B	A	B	D	B	D	B	B	B	B	D	D
First Cost		A	A*	A	A	A	A	A	A	C	D	B	B	B	B	C	C	D	D
Operating Cost		A	A	A	A	A	A	B	B	C	D	C	C	B	C	C	D	D	D
Comfort	Crescine	A	A	B	B	A	A	A	A	A	A	D	B	A	C	C	A	A	A
Small Room (20 x 20')	Lengthwise	A	A	B	B	A	A	A	A	A	A	D	C	A	C	C	A	A	A
Comfort	Crescine	A	A	C	C	C	C	B	C	A	A	D	C	B	D	D	A	A	A
Medium Room (40 x 60')	Lengthwise	A	A	C	C	C	A	A	A	A	A	D	D	B	D	D	C	A	A
Comfort	Crescine	A	A	D	D	D	D	C	D	B	A	D	C	C	D	D	A	A	A
Large Room (100 x 120')	Lengthwise	A	A	D	D	A	B	A	A	B	A	D	D	C	D	D	D	A	B

Comfort

The comfort, or quality, of the illumination provided by a lighting system takes into consideration:

Brightness of the source

Luminaire light distribution and proper brightness ratios and contrasts

Proper shielding of the source

Overall room conditions, such as proper brightness patterns and ratios between visually adjacent surfaces, as well as between work and work surfaces and other room areas or background.

To correlate all these features into one comprehensible condition to produce the desired result in terms of comfort has always been a difficult thing to achieve, even by the experienced lighting engineer.

In appraising the comfort of the lighting systems analyzed here, the Harrison-Meaker method of glare rating has been used. It was felt that this method provided a relatively valid figure of merit from the standpoint of comfort, applies widely to varying types of luminaires under given room conditions, and is as simple to apply as the lumen method in computing footcandles.

In calculating the "glare factors" the Harrison-Meaker method takes into account the basic elements of room conditions in terms of reflection factors of: ceiling — 75 per cent, walls — 50 per cent, and work surfaces — 15 per cent. Ratings used in Table IV are based on conditions shown in Fig. 5, with glare factor ranges as follows:

A — 20 and below
B — 20 - 30
C — 30 - 45
D — 45 and above

Appearance

Individual opinions on aesthetics vary considerably. Nevertheless, the design of luminaires and their general appearance in a room have a direct bearing on how well the overall installation will appeal to the people who daily occupy the area. The problem to be solved, therefore, is for the "multitude" who occupy office space, taking into account the varied personalities. Individual tastes of the designers or specifiers are to be avoided and consideration given to the office occupants. These considerations may vary by nature of people, locality, class of work being done or for many other reasons. Quite important in the classification of appearance is "how long will that 'appeal' last?" Will it wear well over a long period of time? Or will one tire of its appearance soon? The ratings shown in the table are based upon the opinions of many people. In general, luminaires mounted on the ceiling are considered to give a better appear-

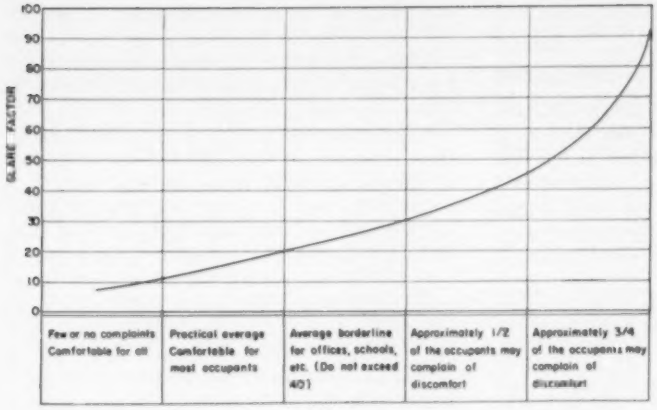


Figure 5. Glare Factor Evaluation Chart.

ance than suspended units, and are so rated in Table IV. Shallow fixtures are preferred to deeper ones. System 10, for instance, carries a lower rating for appearance because too many units are required compared to other systems, where luminaires are mounted below the ceiling. System 11 is rated lower than 14 because louver brightness is higher. System 13 is preferred for architectural appearance above 12, the former having continuous unbroken lines of lens plates. System 18 is rated low in appearance because there are many units breaking up the surface of the ceiling.

Maintenance

In this analysis, maintenance rating is based principally upon the type and number of luminaires required in the installation. As a basis of comparison, the operating costs from Table II, Series II are used, adjusted to 50 footcandles. This includes the *cost of replacing lamps* and the *cost of cleaning*. The following rating prevails:

A — $30 - $45
B — $45 - $60
C — $60 - $75
D — $75 and above.

It should be pointed out that *maintenance* is more than just the cost relation shown above. Construction of a luminaire is of vital importance.

The strength and durability of a luminaire with modern long-lasting finishes, has an important relation to maintenance costs, if the luminaires are to look the same five years or more after they are installed.

Ease of replacing lamps and simplicity in cleaning luminaires cannot be overemphasized, for here time and money in surprising amounts can be saved. The louver construction itself, has a bearing on this. Louvers with cell openings large enough to permit the entrance of a maintenance man's hand — louvers designed so that continued cleaning or relamping will not distort their original shape — louver blades which do not need straightening every time they are handled — all these construction features speed up maintenance.

Accessory equipments — ballasts, lampholders, starters, etc. — have their part in the picture. Approved parts should always be specified for satisfactory trouble-free service.

First Cost

The first cost, or original outlay of money, for installing a new lighting system, like any other part of a building, requires serious consideration. However, the importance of good lighting in sufficient quantity and proper quality has been pretty well established and is more and more appreciated by office planners. Lighting has steadily increased in attaining its rightful percentage position in the overall cost of office buildings. Not many years ago the percentage of lighting for office buildings stood at around 2 per cent of total building cost, wiring included. As illumination levels increased, this relation increased to 5 per cent. Today lighting systems are considered important features of the building layout and rate as much as 15 per cent of building costs. Lighting is finding its true place in modern buildings and managers of office operations acclaim its value in many ways.

There are many methods or types of systems available for office lighting at varying costs to produce the same level of illumination. The cost per square foot of lighting systems shown in Table III, Series II, is the basis upon which ratings are given in Table IV. These are:

A — 70c - $1.00 per sq. ft.
B — $1.00 - $1.30 per sq. ft.

C — $1.30 - $1.60 per sq. ft.
D — $1.60 and above, per sq. ft.

Operating Cost

The annual operating costs of fluorescent lighting systems generally increase as the first cost of lighting systems increase. Compared to the total operating expense of a building, including such items as maintenance, construction, fixed charges and payroll, the annual cost of operating a good lighting system at 50 footcandles would amount to less than 2 per cent.

In rating operating costs in Table IV the values on a square foot basis were taken from Table III, Series II. These are:

A — 25c - 30c per sq. ft.
B — 30c - 35c per sq. ft.
C — 35c - 40c per sq. ft.
D — 40c and above, per sq. ft.

Cost Comparisons with Other Comfort Demands

Is the recommended level of 50 footcandles justified by the cost of installing and maintaining it?

CHART II.—Building Costs and Operating Expenses.

Average Values for Offices

2000 Hours Operation — 2½c/KWH

First Cost per Sq. Ft.

	30 FC		50 FC
LIGHTING AND WIRING Including luminaires, panel boards and branch circuits	$ .60		$ 1.00
BUILDING* U. S. Average		$12.50	
EQUIPMENT Including desks, chairs, tables, typewriters, comptometers, etc.		3.00	
		$15.50	
TOTAL Including wiring and lighting...	$16.10		$16.50

Operating Cost per 100 Sq. Ft. per Hour

	30 FC		50 FC
LIGHTING AND WIRING Including amortization, lamps, energy and cleaning	$ .0096		$ .0160
BUILDING** U. S. Average *Operating* Including cleaning, electric system, heating and ventilation, plumbing, elevators, general expense of offices and building		$ .049	
Construction Including alterations, repairs, maintenance and tenant decorating		.009	
Fixed Charges Including fire insurance, property taxes and depreciation		.031	
EQUIPMENT Including repairs, taxes, depreciation, interest, maintenance, insurance, etc.		.024	
LABOR		1.500	
		$ 1.613	
TOTAL Including wiring and lighting...	$ 1.6226		$ 1.6290

*The Dow Service Real Estate Valuation Calculator.
**Office Building Experience Exchange Report.

Wouldn't it be vastly more economical to provide, say, only 30 footcandles? Not at all. The answer is evident from Chart II, which shows slight differences in the breakdown of costs for 50-footcandle against 30-footcandle levels.

It is interesting, also, to compare the costs of these recommended illumination levels with those of other comforts or necessities now taken as a matter of course. No doubt great sums of money could be saved by office management if high desks without chairs (to say nothing of posture chairs) were still in order. Office life could go on at 40° room temperature. Employees could manage to walk up 15 flights, if management dispensed with costly elevator service. Such conditions are, of course, inconceivable — they wouldn't be tolerated today, under any circumstances, whatever sums of money could be saved.

There are other elements of human comfort which are quickly unfolding themselves, and with equal importance. They are:

Good Lighting — for ease in seeing
Light Furniture — for comfort of vision
Sound Proofing — for aid in concentration
Air-Conditioning — to combat discomfort due to heat

These things, too, are at the threshold of being accepted as necessary to human efficiency and comfort and are already being taken for granted by architects, realtors, management and others advanced in the art of dealing with and handling people.

What are the costs of these comforts? Current approximate costs are:

	Average Cost per sq. ft.
Good Lighting	$1.00
Acoustical Ceiling	1.00
Furniture and office machines	3.00
Air-Conditioning	3.00

Conclusion

It is evident from Chart I, that the cost of fluorescent lighting systems using different types of luminaires to produce 50 footcandles varies considerably. This chart also shows that Troffer lighting systems in a given comfort range are more costly than lighting systems employing luminaires below-the-ceiling. However, cost does not necessarily control the degree of comfort provided by a lighting system as noted in Table IV.

A close study of costs in Chart I, will show that a metal acoustical ceiling with T-Bar construction using snap-in type Troffers will cost only slightly more than Troffers installed in plaster ceilings. For example: System 17 provides comfortable lighting in a large room at $1.78 per square foot in a plaster

ceiling. A fair average cost for such a ceiling is $0.65 per square foot, the overall cost being $2.43 per square foot. In an acoustical ceiling the cost per square foot becomes $2.45, where the lighting is $1.45 and the ceiling $1.00 per square foot. The added comfort due to noise reduction is obviously worthy of serious consideration.

Some luminaires are acceptable from a comfort standpoint in small rooms and yet undesirable in large rooms as shown in Table IV. For example: System 3 (luminaires with glass side panels), may be satisfactory in a small room but complaints of discomfort would most likely be registered in a large room. System 11 (Troffers, louvered and equipped with three 40-watt lamps), is undesirable for all the room sizes cited.

When the ultimate in comfort is sought, the lighting system with the lowest glare rating is most desirable. For instance, the computed values for System 10 are actually lower than System 1. For those cases where the most exacting visual tasks are performed, System 10 may be desired in spite of the fact that the first cost and operating cost would be over twice as much as System 1. But unless the best maintenance schedules are followed with System 10 the reverse situation may prevail after the installation has been in service for a short time.

Acknowledgments

The author is indebted to many people and organizations of wide experience who devoted a great deal of time to supplying information for this paper. Particular acknowledgment is given the following: Mr. Richard Osborne, Osborne Electric Co., Electrical Contractors and Engineers, St. Louis; Mr. Phelps Meaker, General Electric Lamp Dept., Nela Park; Messrs. G. Gusrae, M. Edmonds and A. Sitkin, Voorhees Walker Foley and Smith, Architects, New York; Mr. Paul J. Washburn, Johns-Manville Sales Corp., New York; Mr. Myron L. Matthews, The Dow Service, Inc., New York; Mr. I. K. Smith, National Association of Building Owners and Managers, Chicago; Mr. R. D. Bradley, Day-Brite Lighting, Inc., St. Louis.

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DISCUSSION

ALEX SITKIN*: Our experience in the past few years with the design of office and laboratory buildings has shown that the module used in design varies from five to twelve feet, with the usual module being ten feet. This allows for a possible subdivision of office spaces every ten feet and almost invariably dictates the spacing of the lighting fixtures. Such a limitation of fixture spacing has an effect on the selection of the lighting equipment, particularly since the comfort of any system should take into account both the minimum (ten-foot) office as well as the large open space. Both of these conditions may take place simultaneously in the same building and, of course, are subject to change with a change of tenancy.

Table II of the paper which gives cost comparisons of various lighting systems under consideration could be considerably modified by differences in cost in various parts of the United States. Since this table assumes certain average costs which may be prevalent in only one particular part of the country, I feel that Mr. Taylor should attempt to give some explanation regarding the variation in costs in various parts of the country as well as the effect that such variations would have on the cost of data presented.

Chart II is particularly interesting in bringing out the fact that the lighting in an office building represents a very small part of the over-all cost. It is surprising to note the extremely low percentage difference in operating cost between a 30- and a 50-footcandle installation. Even more surprising is the fact that 50-footcandle lighting seems to represent less than 1 per cent of the over-all operating cost of an office building operation. Cost comparisons are usually made for almost every major office building prior to construction and although the author's figures represent a careful compilation of data, it may be found erroneous to apply these data indiscriminately to office buildings, as is the situation in any other engineering design work where the particular case in point must be considered. Here again, Chart II assumes certain average building costs and it would be

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of interest to know how these costs vary in certain large cities in the United States.

It is pleasing indeed to find that this analysis places a high degree of emphasis upon the glare rating of various fixtures in a particular area. The evaluation of any lighting system in any space occupied by people engaged in seeing tasks in dependent to a very large degree upon the visual comfort achieved by the lighting system. More recognition of this phenomenon should be made by all those engaged in the design and specification of lighting systems.

H. E. D'ANDRADE*: Mr. Taylor is to be commended for his courage in boldly attacking a difficult economic problem. An immense amount of practical information is summarized in his paper, and on the whole his conclusions are sound. If there are differences of opinion, they ought not to detract from the value of the fundamentals presented in this paper.

In Table IV of this paper, Mr. Taylor's classification of luminaires under "Appearance" agrees with the prevalence of opinion among architects and designers. Architects usually prefer an office with recessed fixtures because of the smoother ceiling appearance. Their second choice would be an office with ceiling-type fixtures, and their third choice an office with suspended fixtures. Reasoning along these lines, I would be inclined to lift his "C" and "D" ratings for Troffers to a "B" classification. However, there are architects who would agree with Mr .Taylor's ratings because they do not like long lines of light. They would prefer "squares" or "rectangles" of recessed fixtures.

Another merit of this paper is its comparative ratings of "comfort" using the quantitative Glare-Ratings first developed by Ward Harrison. Here we find all fixtures rated in accordance with mathematical calculations, and not in accordance with personal opinions. Let us hope that this step marks the beginning of an era in which lighting systems will be popularly rated for "glare" as well as "efficiency." In some cases, the comfort ratings as developed by Mr. Taylor are in accordance with experience, though not in accord with some popular beliefs. For instance, his ratings of the Troffer with a low brightness 40-watt lamp (luminaire #18; Table IV) show a consistent level of higher comfort, as compared with a two-lamp Troffer equipped with glass panels or lenses. The low brightness of the 40-watt, T-17 lamp (920 footlamberts) gives it a better rating than the two-lamp glass enclosed Troffer, which would be at least twice as bright. Here it is well to remark that glass or plastic covered Troffers bring a bright luminous surface down to the ceiling, whereas open or baffled Troffers with a 45° cut-off are not visible at the farther end of a large room. Sometimes one cannot tell whether the "open" Troffers at the end of a large room are "off" because there are no visible light sources.

For these reasons, Fixture #18 with the low-brightness Troffer hardly seems to deserve a "D" for "Appearance" in Table IV, and I should like to ask Mr. Taylor the reason for this rating. Likewise, the "Maintenance" rating of "D" seems low, inasmuch as the open fixture is easy to clean. Certainly it is easier to clean than Fixture #17, which has the same maintenance rating in spite of its baffles.

Summarizing, then, Mr. Taylor's paper is sure to prove an interesting and valuable contribution to Office Lighting Practice, and in spite of minor points of difference, it will be useful to architects, designers and engineers.

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H. L. LOGAN*: Accepting the premises on which Mr. Taylor has based the really vast amount of work this paper has required, Mr. Taylor has done a splendid job. The paper is interesting and contains a wealth of helpful data. It will answer many practical questions that lighting engineers are constantly facing and I am sure it will be found to be a very useful piece of work.

I would like my discussion to stop right here. It could, but for the last item in the paper — Table IV — headed "Rating Classification for Office Lighting Systems."

I know of no professional group that seems to proceed so eagerly towards making their services unnecessary, as do lighting engineers. The more complex that lighting becomes the more does the lighting engineer struggle to "simplify" it so that a layman can run a finger down a table and say to himself: "That's the right thing for my job. Now all I have to do is to tell a contractor to buy them and put them in."

These things tend to become a substitute for engineers and engineering — for which there is no true substitute. They are also part of a pattern of thought that is spreading in this country, and is infiltrating every phase of our activities; a pattern about which we are being continually warned. You may be interested in knowing, if you do not already know it, that grading and rating schemes are one of the favorite devices by which totalitarian and socialistic governments control the flow of products within their countries, and limit the products to those in which the ruling clique have an interest.

The more rating and grading schemes are adopted to further the ends of particular groups, the more completely is the ground prepared for the next step; and the last step in this sequence is always Forcible Regimentation.

You will have gathered by now that I am opposed to rating schemes — in toto! A very important reason is that no matter how carefully and honestly they are prepared, they must, by their very nature, misrepresent the truth. Lighting, being one of those activities that affect the responses of people, is such a complex thing that a rating scheme which reflected this enormous complexity would be too complex to use. So selected items are considered in order to simplify matters; but every simplification is a step away from the truth. Rating systems identify things as the same thing that are not the same thing; or they identify different things as similar things, ignoring the differences, and so ignoring the very facts that account for the different responses of people. For example, this rating scheme stops at interiors 120 feet long. The implied assumption is that what is true for 120 feet is true for 200 feet or 400 feet. I recently had occasion to make recommendations for a drafting room 400 feet long. The client had a room 200 feet long in operation, with very satisfactory and comfortable lighting. When checked for the 400 feet long room the same equipment was found definitely uncomfortable, because it happened to have a little light coming out at very high angles. Down the last half of this long room the troffers ran together as far as the eye was concerned into one solid mass, and the farther away they were the brighter they got because of this high angle light, but by extrapolation from a rating chart the false conclusion would have occurred that the installation would have been good for a room 400 feet long.

Rating tables have been likened to aspirin. They can be used in simple situations, which means in plain language for

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the man whose job won't pay the cost of an engineering study. However, when one needs professional advice, and a thorough study resulting in a detailed prescription for his lighting problem, he must go deeper and consider many more factors, and he must integrate all these in terms of the individual job.

It would, therefore, be unfortunate, it seems to me, if the industry accepted any simple panacea to cover all kinds of interiors, or even office lighting, school lighting or any other general applications; unfortunate in the long run that is, for the industry, for the individual lighting engineer, and for the ultimate user.

Good lighting practice will continue to come from the actions of enterprising individual engineers in the future, as it has done in the past, and not from the results of the regimentation of the industry by rating systems, no matter how conscientiously prepared and well-intended.

While I am on this subject I would like to mention a misunderstanding that seems to have grown up about the flux-analysis method of design being a rating system. It is not a rating system and cannot be used as such. It does not show how good or how bad a proposed lighting system may be (whatever "good" or "bad" means in this connection). It simply shows whether or not a proposed lighting system will duplicate the principal distributional features of an optimum natural field of view. If the proposed system does not duplicate a natural distribution there is nothing in the method to show how "bad" the failure is. All it shows is that this particular solution didn't so-to-speak, make the grade. There is no need for rating degrees of failure when the method inherently discards such failures, irrespective of their unknown degree.

Use of the method has sharpened my distrust of rating methods because it has shown, on more than one occasion, that equipment with a poor score, ratingwise, is an appropriate answer to some individual situation, and that equipment with a good rating may be less appropriate, or even the least appropriate solution in a particular case.

To return to Mr. Taylor's paper, I am particularly impressed by the data in Tables I, II and III, and I feel sure that the data will be useful and helpful to many lighting engineers. We are in need of all the information of this kind that we can get.

DOMINA EBERLE SPENCER*: Though the aims and general method of approach used in Mr. Taylor's paper are indeed laudable, there are several points on which I should like to make constructive criticism.

In the first place, the traditional method of calculating coefficients of utilization has been used. As all of you know, this method is based on the measurements made by Ward Harrison back in 1915. In those days, no one thought of using anything but black floors, and the luminaires were vastly different from those used today. As a result, when we have modern luminaires and the 30% floors recommended by Mr. Taylor, the coefficients of utilization extrapolated from the Ward Harrison data are often seriously in error.

As an example, consider the luminous-indirect type of luminaire. For the three rooms cited in his paper, Mr. Taylor gives the following coefficients of utilization:

Small room	$k_u = 0.25$
Medium room	$k_u = 0.36$
Large room	$k_u = 0.42$

If we use the modern method of calculation which takes into account interflections of light, the results are strikingly different. Coradeschi and Innis[1] have made measurements on this particular type of luminaire and give for the three rooms:

Small room	$k_u = 0.40$
Medium room	$k_u = 0.57$
Large room	$k_u = 0.64$

Thus the luminous-indirect luminaire is penalized by being assigned coefficients of utilization that are about 60% of their correct value.

The second question I should like to raise concerns the maintenance factors used by Mr. Taylor. Are they merely guesses or are they based on experimental measurements? Mr. Taylor assigns a maintenance factor of 0.60 to the luminous indirect luminaire and says it must be cleaned 1¾ times per year. According to actual experimental measurements[2] the maintenance factor for luminous-indirect lighting should be 0.74 if the luminaires are cleaned once a year and lamps are replaced as they burn out. On the other hand, Mr. Taylor uses maintenance factors of 0.70 to 0.75 for louvered fixtures. I strongly suspect that these are much too high, as the light must go through the dust film many times before it escapes from the louver.

The net result of these two steps is to impose a severe penalty on luminous-indirect lighting. With high reflectances the luminous-indirect system is quite economical:

Power load for 50 lumen ft^{-2}

	Taylor	Coradeschi and Innis
Small room	6.60 watt ft^{-2}	3.00 watt ft^{-2}
Medium room	4.62 watt ft^{-2}	2.10 watt ft^{-2}
Large room	3.94 watt ft^{-2}	1.88 watt ft^{-2}

These corrected figures compare favorably with those cited by Taylor for hanging louvered fixtures and for Troffers.

The next question I would like to raise is why Mr. Taylor has entirely omitted the ideal type of office lighting: *luminous ceilings*. For luminous ceilings we have a maintenance factor[3] of 0.87, higher than any of Taylor's luminaires. If luminous ceilings were used in the offices discussed in this paper the results would be:

	Coefficient of utilization	Power load for 50 lumen ft^{-2}
Small room	0.48	2.12 watt ft^{-2}
Medium room	0.68	1.50
Large room	0.75	1.36

Thus, we have better maintenance, lower power load, and better lighting with luminous ceilings than for any of the luminaires considered.

Mr. Taylor cites as average current costs: \$1.00 ft^{-2} for good lighting and \$1.00 ft^{-2} for acoustical ceilings, or \$2.00 ft^{-2} for the combination of lighting and acoustics. But experience to date has indicated that the cost of luminous ceilings combined with acoustic fins has always been below \$2.00 ft^{-2} if the system is properly designed. Thus, ideal office lighting is available today at a cost which is called average by Mr. Taylor.

Mr. Taylor has asked me to say a word about the application of the rating system[4] which Professor Moon and I developed several years ago. I have worked out the details of applying our rating scheme to a hanging louvered fixture (#1) and a louvered Troffer (#17) and obtained in the first case a rating of 43 and in the second 45, both failing grades. On the other hand, corresponding ratings for luminous indirect luminaires and luminous ceilings are 91 and 93 respectively. The low ratings for louvered fixtures and for troffers are caused by the non-uniform helios distribution, insufficient light on vertical surfaces, specular reflections, shadows, and poor psychological effect associated with

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a spotty or striped ceiling. Our rating system differs from the Harrison-Meaker-Guth glare rating system in that it requires good visual conditions for work in all locations in the room and does not attempt a fine discrimination between inadequate luminaires. It also considers head and hand shadows and reflected glare to be of great importance as they confront the worker all of the time when he looks down at his task. For the last five years, Dr. Harrison has been admitting that he should consider reflected glare, but to the best of my knowledge he has not gotten around to doing anything about it. In the meantime, the application of the Harrison-Meaker-Guth glare rating formula is continuing to mislead people into designing lighting with maximum reflected glare.

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2. D. E. Spencer and Salma Malkiel: "A Photometric Investigation of Dust," *J. Franklin Institute*, 245, p. 389-402 (1948).

3. Spencer, Headley and Martin: "Luminous-Ceiling Lighting for a Machine Shop," ILLUMINATING ENGINEERING, 46, p. 26-28 (1951).

4. Moon and Spencer: *Lighting Design*, Addison-Wesley Press, Cambridge, Massachusetts, Chap. IX (1948).

G. P. WAKEFIELD and T. D. WAKEFIELD*: A reading of Mr. Taylor's paper reveals that we have the old battle of Goliath Footcandle about to slay David Quality in the war which has been going on for many years. The trouble, of course, is that the stones in David Quality's sling-shot are primarily of igneous formation which are still hot and have not yet crystallized. Therefore, the outcome of the battle of these two adversaries will not be known for some time. We are always reminded of this comparison whenever we see lighting units compared in tabular form with the footings ending in equal footcandles. This paper presents, for comparison reasons, all luminaires on an equal basis of 50 footcandles without regard to comfort in the reflected glare zone. This zone is completely neglected! We know that a louvered bottom unit is not the same as a luminous indirect, and yet, Mr. Taylor compares them as the same, except giving "A" for quality in a tabular form with appearance, maintenance, first cost, and operating cost.

If we may discount appearance by saying that appearance is only important to the person who glances casually into the room and not important to the person who performs a close visual taks in that room, that maintenance is of prime importance to the janitor rather than to the occupant, that first cost and operating cost of the system have nothing to do with the efficiency and comfort of the worker in that room, we can put David Quality on a pedestal high enough to at least be of equal stature with Goliath Footcandle.

And about Quality having stones not fully crystallized, primarily hot, amorphous, and sometimes sticky, we can state, without our being able to prove it, that we believe a quality job with a third less footcandles is equal to 50 footcandles of some of the types which he has listed or recommended as equals.

Our method of comparison would have been on a basis of using twelve units of each type rather than taking the number of units necessary to deliver 50 footcandles.

Furthermore, we do not see how Mr. Taylor would put 28 luminous indirect units in a 20' by 20' room for 50 footcandles. Our figures show that eighteen units would be required, using the reflectances readily available today.

Going back to the basis of comparing an equal number of units, here is the difference of first cost in the unit for unit method.

Our figures based on comfort:

Unit No. 1 (50 ft-c. 12 units)	No. 10 (34 ft-c. 12 units)
Costs — $224.00	$484.00

Mr. Taylor's figures based on equal ft-c. (50)

Unit No.1 (12 units)	No. 10 (28 units)
Costs — $224.00	$1,131.00

In other words, the costs are 1 to 2 instead of 1 to 5.

Using 18 luminous indirects versus 12 louvered units for 50 ft-c. comparison costs run something like this:

Our figure based on equal ft-c. (50)

Unit No. 1	Unit No. 10
Costs — $224.00	$727.00

This ratio is 1 to 3¼.

Quality lighting is expensive compared to bare bottom units but not as expensive as Mr. Taylor implies. It is cheap compared to 1600 footlamberts of potential reflected glare stabbing the worker's eyes 8 hours a day.

For those who wish to continue on a footcandle comparison basis, we invite their attention to Mr. C. W. Macy's article in the November 1949 issue of *Electrical West* entitled "The Office Lighting Complaint — Too Much Glare." In it he uses his years of experience in following up on installations after the manufacturer has shipped the job, the distributor has delivered, and the contractor has installed it. He concludes that "excessive brightness and reflected brightness must be eliminated if we are to satisfy customers, and believe it or not, this is relatively easy to accomplish in almost all cases."

His experience, and that of many others, indicates that office lighting luminaires should be designed with a maximum brightness of 333 footlamberts from horizontal down to directly beneath the unit.

If the building manager is to design for straight economics, he should follow Mr. Taylor's paper explicitly. If he is considering the worker's visual comfort and efficiency in an environment in which the worker will spend a third of his lifetime, we feel that more serious consideration should be given to that intangible Quality.

Perhaps the I.E.S. Research Committe can some day give that proof which will crystallize the stones in David Quality's sling-shot to knock out Goliath Footcandle forever.

JOHN J. NEIDHART*: Mr. Taylor has made an excellent presentation of a logical approach to the difficult problem of selecting the type of luminaire to be used in lighting a general office. He has gathered and made available a wealth of information that can be of considerable value to the man who sells, plans, or specifies lighting. To make proper use of this information, however, the user should be fully aware of its limitations and the controversial issues involved.

The first problem in making an appraisal of lighting systems is the selection of a limited number of luminaires which are representative of the many types available. Mr. Taylor has included many of the more popular basic types in his 18 systems, but it is difficult to make direct comparisons between any two systems to uncover basic economic characteristics because there are too many variables. Many of these variables may not be readily apparent to the reader and if overlooked, will lead to erroneous conclusions. For example, if one wished to determine the relative economics of the two- and four-lamp luminaires, he might com-

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*Westinghouse Electric Corporation, Cleveland, Ohio.

pare Systems #1 and #4. From this he would falsely conclude that two-lamp systems are less expensive than four-lamp systems. Reference to the text discloses, however, that these systems are not comparable since #2 has metal sides and #4 has luminous sides. There are also doubtless other differences affecting cost and efficiency. Systems #4 and #6 are obviously more comparable, but they are not truly comparable with different shielding and construction. Thus, the analysis fails to show the 20-30% economic advantage of four-lamp luminaires over equipment for two lamps that we have found in our numerous cost analyses in which two- and four-lamp units of identical construction are compared.

In selecting the only representative luminaire for semi-indirect lighting (#10), Mr. Taylor chose a two-lamp unit. This type of lighting is admittedly expensive, but the use of two-lamp units in the comparison overemphasizes the higher cost of quality lighting. Four-lamp semi-indirect luminaires are available and are much more applicable when a 50-footcandle level is desired. This high quality installation was given a "Poor" appearance rating because of the large number of suspended (2-lamp) luminaires required. I submit for an appearance rating this illustration of a large semi-indirect installntion right here in Los Angeles. These are two-lamp units, but the illumination is only 30-35 footcandles. Well over 50 footcandles could be maintained with a virtually identical installation of four-lamp units. (Slide shown at Pasadena Conference.)

Mr. Taylor states that he bases his comfort ratings upon the Harrison-Meaker Glare Rating system. This is an excellent means of rating *direct* glare, but it does not pretend to appraise *reflected* glare. Reflected glare has been disregarded entirely in this comparison, but it is something that should be considered in a comprehensive appraisal of office lighting such as this. It is inconceivable that louvered bottom units such as #1 and #2 be given the same *comfort* rating as #10 and #18 (when viewed crosswise). The higher degree of comfort that may be expected from semi-indirect installations, is the only reason that they are being installed despite their higher cost and increased maintenance. I also find the extreme difference in comfort ratings between two- and four-lamp units hard to justify as a basic fact, although I do not concede the glare ratings for the particular units studied could easily come out that way.

I noted with same surprise that the maintenance factors given in the general data were quite high. In many instances they are higher than the "Good" factors published in the I.E.S. Handbook for comparable equipment. Yet, the number of cleanings estimated were in the order of only once a year. Surely such infrequent cleaning cannot be considered as "Good" let alone something better than that.

Although my comments may seem rather extensive, they are offered primarily to call attention to a few of the qualifying factors and the limitations of an analysis of this sort. It is not practicable to include all of the qualifications and reasons for each conclusion in such a comprehensive appraisal, and the reader should be cautioned not to draw general conclusions from the cost and appraisal tables. The appraisal is valid only for the luminaires selected and the particular set of conditions and costs used by Mr. Taylor. It is an excellent example of a logical approach to a difficult problem and Mr. Taylor is to be commended for his thorough coverage (except for the reflected glare omission) of such a complex subject. It should be used only as an example with luminaire costs, power rate, operating hours, labor and other variables adjusted as required to suit the particular application being studied.

R. L. Oetting*: Mr. Taylor has covered a lot of territory in this paper — so much that there is bound to be considerable discussion, some of which may be sharply critical. Nevertheless the paper should be recommended to all those involved, even remotely, in the design, sale, or use of office lighting. By relating lighting costs to other costs of office operation, the paper shows the differentials among lighting systems to be of little consequence and should encourage the development, specification and use of only the highest quality lighting. The simultaneous appraisal of costs and performance is an essential part of engineering and has too often been missing in our literature.

The author's position in the industry recommends the acceptance of his cost data, particularly as regards equipments and installation charges. His including amortization as part of "operating" cost, especially in Table III may be misleading to many. Separating actual operating expense from amortization is desirable since different organizations and even different departments within an organization will assign different importance to the two. This is particularly true in those instances when new lighting equipment is purchased as an item of current expense — conventional accounting rules to the contrary. The operating costs of Table III will be appreciably lower and to some degree the relationships will change when amortization costs are excluded.

In reaching over-all costs conclusions, the author is forced to travel the uncertain road of assumptions. His assignment of a .70 maintenance factor to open, recessed, single-lamp troffers (#18) and a 7% higher value of .75 to suspended, multi-lamp, louvered units is bound to be questioned. Nor is it quite clear as to how these figures are to be interpreted. Mr. Taylor seems to compensate doubly for the assumed maintenance characteristics of the open troffer by not only increasing the number of units but also by increasing the frequency of cleaning. The latter (at 9.6 months) should net a maintenance factor for the troffers at least as favorable as that assigned to the suspended units on a 12-month schedule (which isn't often enough for most locations). The 50-cent cleaning charge for the open troffers is also questionable when the same amount is applied to 4-foot, two-lamp, louvered Troffers and suspended units. Assumptions such as these appear to cause the low "D" maintenance rating for the simple #17 and #18 troffers in Table IV. This is at variance with the opinion of many users of these types and points up the need for comparative data under identical or quantitatively identified atmosphere conditions.

Quantitative evaluations have commercial, as well as engineering value. The author demonstrates the fact in his use of the Harrison Meaker glare rating technique. His presentation illustrates how the system cuts through the confusion and ambiguity of shielding angles, zonal or spot brightnesses and installation conditions to the ultimate objective — will the result be acceptably comfortable? Mr. Taylor's proposal of A-B-C-D comfort steps should receive consideration. The fact that glare ratings are abstract values seems to have retarded their use commercially. It is difficult to understand this objection since coefficients of utilization and visibility levels are similarly devoid of dimensions. But, if letter ratings will hasten the acceptance of the system, the proposal warrants serious consideration even though it may seem technically unnecessary.

The legend in the center column of Figure 5 might better read "Maximum range for reasonable acceptance in offices,

*General Electric Company, Nela Park, Cleveland, Ohio.

schools, etc.'' The limiting value of the block is 30, and not 40. The term ''borderline'' needs more detailed definition if it is to be significant.

In thanking Mr. Taylor for the over-all perspective he has given to the low cost of quality lighting in offices, we would like to add one comment. He has made reference to and has based his calculations on the conservative quantity recommendations of the Society. With other office costs increasing, 50 footcandles of high quality illumination are becoming a rational level for ''general'' office work. The Society will render an important service to the public if it will but emphasize that quantity recommendations are estimates as to what is economically justified by the *current* relationship between lighting and other costs in the various fields with which the Practices and Standards are concerned. Mr. Taylor's analyses have shown how conservative our present office recommendations really are.

T. A. Barr*: The contents of this paper are timely and worthy of serious consideration by the illuminating engineer, the architect, the building owner and specifier of lighting equipment. Anyone who delves thoroughly into this paper will realize that the author has devoted a tremendous amount of time to a study of the facts involved in the consideration of modern and efficient office management.

Cost comparisons usually do not appear in an I.E.S. Conference Paper. However, faced with high building, remodeling, and operating costs, the author in his endeavor to give practical consideration to the subject has been forced to include cost comparisons, since the data are correlated with other information necessary for him to form logical conclusions.

The author has prepared this paper in a most orderly manner. He recognizes the situation involved in planning good illumination in offices. He has assembled and recognized the economic factors which are involved in consideration of this subject. He has used our Society's ''Recommended Practice of Office Lighting'' as a criterion in his studies. From the scope and the purpose of the situation he has set up and has clearly shown what the problem is. He has quickly gone to the solution of the problem by clearly analyzing Comfort, Appearance, Maintenance and Cost. He has left the order of importance of these factors up to our own individual judgment.

In appraising comfort, he has used the Harrison-Meaker method which many of us can agree is valid for an appraisal of glare evaluation in the use of the various classes of luminaires under consideration. Some of our membership may prefer an appraisal by the methods proposed by Mr. Logan or Mr. Moon. No matter what method is used for glare appraisal, it is evident that some common knowledge of comfort should be adopted, rather than having each individual depend upon his own judgment of what constitutes glare in an office interior.

In considering appearance the author recognizes the fact that ''individual tastes'' of the designers or specifiers are to be avoided and consideration should be given to the office occupants.

Mr. Taylor recognizes the fact that the building owner is interested in maintenance that can be accomplished quickly at a reasonable cost. He is aware of the fact that a lighting system in an office must continually be kept in good operating condition in order to give the desired results over a long period of time. In Table I the author uses an average lamp life of 6000 hours for the 40-watt T-17 lamp. This seems low from actual experience. I wonder if the author would consider 7500 hours as a basis the same as the 40-watt T-12 lamp? Would not group replacement be the ultimate answer in lamp maintenance? In Table II the cost of cleaning luminaire No. 18 seems high.

In the question of building and operating costs, the author has fortified himself with average cost data which seems to be beyond dispute. A careful analysis of the Charts and Figures 2, 3 and 4 is very revealing. Chart II showing building costs and operating expenses reveals the fact that not only first costs but operating cost expenses clearly indicate that the difference in cost between an ordinary office lighting installation and a quality lighting installation is negligible on an over-all building operating basis.

The author is aware of the fact that maximum human relations and human comforts are necessary in promoting greater human efficiency through superior and faster work with less mistakes and fatigue. All of these benefits mean much to a progressive and farseeing office management who are paying substantial salaries to their office personnel.

With respect to Table IV showing his rating for each luminaire classification for office lighting systems there is a question which the author might answer in his summary. In the consideration of the low brightness troffer luminaire No. 18, he rates the appearance as ''D'' and maintenance as ''D.'' How was this rating arrived at? After a number of years of experience with this type of fixture, it is my conclusion that he could have rated these fixtures much higher in this classification.

Whether our membership concur on all of the suggested methods of arriving at his conclusion seems of little consequence. The paramount point is that this paper incorporates what the author considers is his best solution to this important problem. The character of this paper is such that the author should be congratulated for his work in preparing such a clear, concise and practical solution. It seems to me this paper presents a challenge to our Society since the author has used as a basis our ''Recommended Practice of Office Lighting.'' Furthermore, it stimulates our desire for further action in adopting some method of appraisal that will contribute to more comfortable lighting in our office field.

Is it not our Society's moral obligation first to conduct scientific investigations in the art of proper seeing and secondly, disseminate information in a practical and easily understood form for the use of the public in creating comfortable seeing conditions which we feel are so necessary in the advancement of the Art of Illumination?

R. W. Osborn*: It should be mentioned at the beginning that need for this all inclusive study has existed for some time. As a member of the Electrical Contracting Industry, we are grateful for the wealth of information contained. A progressive commercial industry requires quick methods of accomplishing conclusions to their every-day problems. Many groups contribute to bring about the most satisfactory environment that will lead to greatest efficiency. The author must be included in this group.

We have always been fearful to tell the user of artificial lighting sources that one method of lighting looks better than another. The old saying, ''There is no accounting for taste'' is too often true. If the user says ''Its appearance is not pleasing'' we have always been somewhat helpless, because to him (the user) it was not pleasing. The term

*Central Hudson Gas & Electric Corporation, Poughkeepsie, N. Y.

*Osborn Electric Co., St. Louis, Missouri.

"Comfort" and the explanation of the word as it fits lighting gives us a new tool that will help to establish "what looks good."

There are some surprises for us in the cost study tables.

Slightly more cost is indicated for suspended luminaire mounting on acoustical ceilings compared with plastered ceilings (Table II) while the cost of mounting recessed luminaires in metal acoustic ceilings is considerably less than the plaster installations.

Tables I and II supply us with general data and cost data from which we can check completed estimates for errors. In these days of high pressure estimating it is refreshing to have available a quick reference that can be used in making reasonable comparisons.

The user of lighting equipment must know in most instances his needs and funds available to meet these needs. Table II will be most helpful in this regard. While extreme accuracy is not to be expected, a reasonably intelligent decision can be made through its use.

Chart I will certainly be given much use as a means of setting up budgets for future lighting programs.

Maintenance shows up as a very important factor and we would do well to study even further. Thought could be given to cleaning methods and materials.

Users of industry's products have always wanted to know "What can you give me for money?"

Table IV used in conjunction with another chart helps to show how much comfort various types of lighting can give him for his money.

It never occurred to us that office furniture could be compared to lighting, but the author makes the task quite simple.

We congratulate the author on his efforts and mark it as a success. Too few of us are bold enough to be practical and talk cost in relationship to the technical side of artificial illumination.

THOMAS SMITH KELLY*: Mr. Taylor's paper "Appraisal of Modern Fluorescent Office Lighting Systems" will be a tremendous help to all concerned with the selection and planning of standard fluorescent office lighting. Architects, engineers, representatives of fixture manufacturing companies, office building owners and office users can use the appraisal as a common base from which their lighting systems may be selected.

A casual glance at Table IV reminds us of the importance of proper orientation of certain fixture types in relation to the occupants of the office. By comparing the different types, we find No. 6 and No. 7, while recommended from the standpoint of comfort, when placed in any direction in a small room, become non-acceptable unless carefully oriented in a large office space. Type 13 is found to be recommended only in small offices. Type 11, we find should not be used in any office whether large or small.

Much time can be saved by using the tables as we can easily see and compare the costs of each of the eighteen systems in relation to room sizes and ceiling types. Mr. Taylor has also attempted to classify the various systems from the aesthetic approach. This is a difficult subject and some of those who read the paper will undoubtedly disagree. However, the majority will accept his classifications.

R. L. ZAHOUR**: I am greatly impressed with the presentation and assembly of material in Mr. Taylor's paper. He points out two important items in his cost analysis of various lighting systems; the first cost which is really an immediate pocketbook item; and the operating cost which is an "upkeep" expense. Neither of these can be minimized when planning good lighting. This point is borne out in Chart II which shows that lighting fixture and wiring costs of sixty cents per square foot will give 30 footcandles of threshold illumination where good seeing begins, while 50 footcandles of good lighting for eye comfort and ease of seeing can be had for $1.00 per square foot. In other words, for forty cents per square foot more, you can have 20 more footcandles and better lighting. That's a real bargain for any building owner.

Table III shows System 2 with slimline lamps to be approximately 8% higher in first cost over System 1 involving 40-watt preheat fluorescent lamps. Likewise, slimline System 15 is about 10% higher than 40-watt preheat System 14. While this first cost differential is approximately correct, there is a general trend toward slimline systems. This trend is not due to any difference in the performance of the lamps, but is primarily in favor of the simplified control system in the slimline circuit which definitely cuts labor maintenance costs.

In his illumination calculations, Mr. Taylor has used a life value of 7500 hours for the 40-watt, 48-inch, T-12 preheat fluorescent lamp, and 6000 hours for the 75-watt, 96-inch, T-12 slimline. I would like to point out that that figure of 7500 hours' life for the 40-watt preheat fluorescent lamp is the rated average life at three hours per start. Lamp life is slightly longer for more burning hours per start. Likewise, the 6000 hours' life for the slimline is a value under specified test conditions of 12 hours' per start. Lamp life is somewhat shorter for fewer burning hours per start.

W. W. BOOTH*: Mr. Taylor's paper is a splendid summary of the principal considerations entering into the selection of a system of fluorescent lighting for typical modern office areas. His tabular data and tables of cost computations offer a sound approach to the problem for anyone concerned with cost comparisons. Calculations of this nature enter into the sale of many lighting installations and it is indeed sound practice to give due weight to the several important factors of comfort, appearance, maintenance, first cost and operating cost as cited by the author. Some such pattern as proposed by Mr. Taylor, is worthy of general adoption.

All too frequently a selection is made based solely on one consideration — possibly appearance — possibly over-all efficiency or proper brightness ratio, but often the decision rests on the matter of initial cost. It naturally follows, however, that in a given case it is proper to assign more weight to certain factors entering into the over-all costs or qualities of the system under consideration.

It is apparent that considerable care entered into determining the many items of typical or average cost given in this paper. We should remember that computations must be made specifically to fit the individual case since all items of cost will vary, based on quantities involved, local code requirements, actual local cost of wiring, installation, equipment and maintenance.

There are a great many fixture designs on the market which might fall into one or the other of the eighteen prototypes sketched and covered by general description. The coefficients of utilization of some of these might be considerably different, plus or minus, from the figure used by

*Lighting Consultant, New York.

**Westinghouse Electric Corporation, Bloomfield, N. J.

*General Electric Supply Corporation, Bridgeport, Connecticut.

Mr. Taylor for his cost computations. The reader should be cautioned against categorically applying these data to all fixtures which fall within these general description classifications.

It would be interesting to speculate on the variations of design and other types of equipment that are different from those included in this study. The sound procedure outlined by Mr. Taylor, therefore, argues for a more general use of distribution curve data since by this means alone we gain what we know about the illuminating qualities and performance characteristics needed to develop a similar cost analysis.

Mr. Taylor's paper takes us much nearer the goal line in the practice of illuminating engineering and should be quite helpful to the sales quarterback in calling the signal for best over-all lighting results.

R. C. KINNEY*: Mr. Taylor's paper "Appraisal of Modern Fluorescent Office Lighting Systems" is a rare combination of carefully gathered authentic background material and original analysis that is so much needed by architects and engineers today. The most important reliable data are combined in such a way with best field practice as to provide shortcuts in application of basic data to specific problems.

There may not and likely will not be complete agreement by all readers in all of the conclusions of the author. This can be expected in the illuminating engineering field where there are usually several alternate methods in arriving at satisfactory lighting for a given problem.

We must all agree, however, that the materials gathered are useful, carefully edited and of great importance to all interested in analyzing the merits of individual typical luminaires for specific problems.

PAUL J. WASHBURN**: The architectural acoustical industry had its origin at the turn of the century back about 1900 when Dr. Wallace C. Sabine conducted his original investigations at Harvard University on ways and means of improving hearing conditions in a lecture room. At that time, Dr. Sabine was professor of physics at Harvard. We will not take the time to go into the various fascinating discoveries that resulted from Dr. Sabine's original investigations. We should add, however, that he was called upon to correct the acoustics of a number of auditoriums during the years that immediately followed the solution of the original problem.

Acoustical materials were first offered commercially early in 1911. Again, the usage was limited to auditorium for the purpose of improving the acoustics — the basic concept of which was to provide "optimum reverberation." Acoustical materials were used to increase comfort in offices. It was found at that time that ordinary conversations could be conducted with greater ease in offices that were treated with acoustical or sound absorbing materials. Conversing over telephones became less of a problem and the conference rooms could be used more successfully. In that period, typewriters and office machinery of one type or another were beginning to be manufactured and sold extensively. It was at this point that sound absorbing materials were first used for the purpose of noise reduction — to reduce the clatter of noises generated by office machines.

In the middle and late 1920s, several companies, contemplating the installation of large quantities of sound absorbing materials, investigated the cost versus performance to justify the appropriation. Perhaps most work in this respect was done by insurance companies or telegraph and telephone companies who had sizeable statistical departments with which these investigations could be made and accurate records maintained on "before installation" and "after installation" efficiencies of the employees. Although some of these records were made public, many of them were not. It will suffice to say that today the insurance companies are among the largest users of sound absorbing materials for office quieting. It has been found that the principle benefits are to increase the efficiency and add to the comfort of employees. A few of these insurance companies taken from a large list are: John Hancock Insurance Co., New York Life Insurance Co., Metropolitan Life Insurance Co., New England Mutual Life Insurance Co., Travellers Insurance Co., Prudential Insurance Co., Mutual Life Insurance Co. As a matter of fact, many business firms in practically all types of industry have standardized on sound absorbing materials for their general and private offices.

There are some acoustic problems in practically every type of building project. These range from noise reduction within the offices to sound transmission and machinery vibration problems. The intensity level of sound (or noise) is measured on a logarithmic scale called the "decibel" scale. The word decibel is encountered rather frequently these days which should not be alarming when one realizes that a decibel scale from 0 to 120 is a measure of sound in the same relative manner that a thermometer measures the degree of hotness or coldness that exists. Zero is at the threshold of hearing and 120 decibels is at the intensity level where the sound is felt as pain instead of heard. Few people can give an accurate definition of a decibel or of a degree Farenheit, for that matter. Nevertheless, frequent use of the thermometer enables the average person to judge the probable degree of comfort that exists by the thermometer reading. It will not be long before the same familiarity will exist with the public in the decibel scale.

There are many factors to be considered when appraising or evaluating an acoustical material, particularly when it is being considered for installation in a commercial office. The following points are listed not necessarily in the sequence of their importance, but rather to indicate points of consideration. The sequence of importance will often vary with the job requirements.

1. Acoustical efficiency of the material.
2. Light reflection coefficient.
3. Ease of maintenance.
4. Engineering details pertaining to its method of erection.
5. Resistance to fire and flame spread.

The perforated metal type of acoustical material rates very high when appraised by these five points. Its acoustic absorbtivity is excellent. The sound absorption coefficient of this material is .85 which represents the percentage of energy absorbed by this material when a sound wave impinges upon it.

Particularly in this interest of good lighting for commercial installations, the light reflection coefficient is very important. Here again, the perforated metal materials with their baked enamel finish, meets the requirements of the illuminating engineer.

Maintenance becomes important in order to preserve both the acoustic and light reflection efficiency of the product. Some materials such as the perforated metal treatments can be washed. If repainting is desired, this too should be possible with the acoustical material selected.

*Graybar Electric Company, Incorporated, New York City.
**Acoustics Department, Johns-Manville, New York, N. Y.

Erection details are particularly important if troffer design of lighting fixtures are to be used. The perforated metal ceilings with the Tee Bar attachment provide excellent means of support for the lighting troffers.

And finally, the acoustical ceiling should be incombustible in accordance with standard fire tests. The perforated metal treatments have this incombustible rating and therefore, can be used in all types of buildings and in all existing building code conditions.

PHELPS MEAKER*: In order to test the usefulness of the Glare Factor approach to lighting comfort evaluation, the most pressing need is to get people to try it out and put it into practice. Mr. Taylor's application of it in his analysis is extremely welcome. The ratings, viewed broadly, are not to be taken as figures of merit for the luminaires, but for the systems as installed, and for the one specific occupancy, in terms of the comfort criteria set up by the lighting designer. For instance, the ratings which are tabulated in this paper have nothing to do with the suitability of similar luminaires for store lighting.

I have recently been much interested in examining the Glare Factor concept and formula in the light of the fact that the quantities involved are identical with those used to evaluate visibility: size, contrast and brightness. It appears that we can reasonably think of Glare Factors as indicators of the ultra-high visibilities of glare sources. This means nothing but conspicuousness. If glare factors are high, people are made inescapably aware of the existence of the glare sources.

Remembering the original concept: "Glare Factors evaluate discomfort while the gaze is raised from the work, and one looks about the room;" we realize that the subject concerns those intervals in the work day when one's seeing function should be resting and relaxed. If conspicuousness of luminaires is high, how can one's eye relax? What they are seeking is plainly visible objects of interesting pattern, at about the same order of brightness as the work.

The more experience with Glare Factor one has, the more often he is aware that brightness ratios of 3 to 1 often appear as the ultimate goal. For instance, in a long low-ceilinged room, distant fixtures should not be brighter than 3 times the work; which means about ¼ candle per sq. inch for most illumination levels. This kind of limitation is particularly necessary if the far wall is dark, offering no large scale pattern; for in such a surface the eyes find nothing to look at, *except the luminaires*, which are the only objects of satisfying visibility. This seems like a more reasonable view of the matter than the old expression: "the eyes are always attracted to a bright object."

Glare Factors, which attempt to evaluate only discomfort due to direct glare should occupy a position in a lighting design procedure commensurate with the need. In other words, there may be inadequate illumination, or a poor working environment, or gloss reflections from shiny surfaces near the work; any of which may present a more serious problem than direct glare. In such a case, it would be unwise not to correct these other ills before giving prime consideration to Glare Factors.

No lighting engineer should be asked to accept a given scheme for comfort evaluation, unless he has a grasp of the basis upon which it is built. The problem becomes one of deciding whether the underlying philosophy is truly applicable to the worker doing critical tasks in an indoor environment.

*General Electric Company, Nela Park, Cleveland, Ohio.

The way in which Mr. Taylor has assigned rating letters instead of using numerical values for Glare Factors is a welcomed experiment. No comfort evaluation system, based on the sensations of as variable a mechanism as a human being, can pretend any high degree of precision. Nor can it be used constructively in a competitive commercial situation if it leads to hair-splitting distinctions. Overlapping categories of excellence and the submerging of minor differences offer a promise of real aid to lighting design. In making comparisons with the BCD method (February 1951 ILLUMINATING ENGINEERING, p. 65-75), we have considered the methods to be equivalent in usefulness, if by the application of either the designer would be led to the same conclusion regarding the suitability of the luminaires in a certain lighting system, without regard to differences in actual numerical values.

GEORGE J. TAYLOR*: Mr. Sitkin points out the possible variation in cost data presented in Table II and Chart II in various parts of the country. Average cost values were determined on the basis of St. Louis being a typical large city where office structures of the type presented in this paper might be erected. Building costs are determined from material costs and wage rates. The Dow Service, Inc., an established firm in this field, publishes up-to-date data on building costs in their "Real Estate Valuation Calculator," based on local cubic foot costs. A few of the cost "modifiers" for various cities (October-December 1950 figures) are as follows:

Atlanta	85	Los Angeles	96
Boston	105	New York	114
Cleveland	109	Philadelphia	107
Chicago	104	Richmond	86
Denver	100	San Francisco	98
Detroit	102	St. Paul	101
St. Louis	102		

Hourly wage rates for electricians vary from (of the above cities cited) $2.25 for Atlanta to $3.00 for New York with Denver at $2.50 and St. Louis at $2.62.

Mr. D'Andrade's substantiating remarks in behalf of the "Appraisal of Lighting Systems" given in the paper are highly appreciated since his training in the lighting profession has been primarily in the architectural field. He is aware of the requirements of architects, designers and engineers in bringing to them data of a practical and comprehensive nature. He agrees that "personal opinion" in rating a lighting system depends upon the individual which is misleading, more often than not. Mathematical calculations as proposed by Harrison-Meaker eliminate the personal elements and provide a scientific approach to an otherwise difficult appraisal. Mr. D'Andrade would lift "C" and "D" ratings for Troffer Systems #17 and #18 to a "B" rating for "Appearance." The luminaires in these systems are constructed of Alzak Aluminum simulating a parabolic shape. It is true that as one looks down the length of the room, crosswise of the luminaires, the low side brightness of the reflecting sides diminishes into the ceiling. Such an effect is desirable and does give the illusion that lighting is provided without luminaires. However, the Troffers in System #17 utilize single 48", T-12, 40-watt lamps, requiring a spacing of rows of approximately 5-foot centers to provide a level of 50 footcandles. System #18 employs single 60", T-17, 40-watt lamps and the rows are spaced on approximately 4-foot centers. The basis of rating is that the

*Author.

greater number of rows there are the greater the number of "breaks" in the ceiling. Bearing this in mind, the rating was given as "D" for System #18, "C" for #17 and "B" for #16. The prismatic lens System #13 was rated "A" because the particular lens used provides low brightness at wide angles with wider row spacings than indicated for aluminum Troffers and a smooth or level ceiling throughout the room whether the units are lighted or unlighted. To answer Mr. D'Andrade's question concerning "Maintenance" costs, it must be remembered that the degree of simplicity in cleaning one luminaire versus another is by no means the criterion in judging an over-all maintenance program. While System #18 uses "open" type Troffers and #17 is equipped with cross baffles, the former requires 504 lineal feet compared with 585 lineal feet for the latter to provide a level of illumination of 50 footcandles in a Series II room. System #18, therefore, requires cleaning 16% more lineal feet than #17. As explained in the section on Maintenance, the analysis in rating maintenance is based on the *cost of replacing lamps* and the *cost of cleaning*. As a basis of comparing System #17 and #18 Table II, Series II is used and the values prorated to provide 50 footcandles in each case. This shows that System #17 maintenance costs amount to $86.80, while #18 costs amount to $83.00. This comparison agrees with Mr. D'Andrade's thinking on the subject of maintenance but when comparing maintenance with other systems in the same manner as outlined above and using the method of rating shown in this paper, both Systems #17 and #18 take a "D" rating.

If it were not for Table IV headed "Rating Classifications of Office Lighting Systems," we would have received high compliments from Mr. Logan in the preparation of this paper, an honor to any author even up to this point. Mr. Logan dislikes simplicity when a layman can run his finger down a table and get an answer. Nor does he have much time for compromises in the selection of lighting systems. The rating table is not proposed for anyone to run his finger up and down and across the columns in selecting a lighting system. It is merely given as a guide in presenting some fundamental facts simple enough for the buying public to defend itself from "sales talks" on products and illumination quality. Architects, engineers and other applying illumination exercise their knowledge in studying every lighting problem confronting them but have to keep clear of theoretical and complicated lighting analysis. If it were not for this, these specifiers of lighting would merely check a series of luminaires from coefficient of utilization tables and pick one with the highest value. Obviously, this is not being done because luminaires used in offices, at least, have a "commercial" appearance. But it is being done in many instances where commercial luminaires are not suitable for office lighting. The Rating Classification Table IV will prove useful to these practical men who do specify lighting. Mr. Logan refers to the fact that my paper stops at 120 feet in length for a large room. He states that the conditions for comfort given in the paper would not hold true for rooms 200′ to 400′ feet long. While Mr. Logan's remarks in this connection are true, it must be admitted that these room sizes are very much in the minority in our everyday lighting problems. Nevertheless, Table IV brings out some interesting facts in this regard. For instance, System #3 shows a comfort rating classified as "B" in a room 20′ by 20′, "C" in a room 40′ by 60′, and "D" in a room 60′ by 120′. As room sizes increase, the comfort of seeing goes down. Yet, if a luminaire were designed with proper brightness control such as System #1, the classification remains "A" for all the room sizes given in the paper. In the mathematical calculations used to compute glare factors from the method proposed by Harrison-Meaker there is a sacrifice in comfort as room sizes increase. It is likely that System #1 would fall into a "B" classification with the larger room sizes cited by Mr. Logan. This points to one advantage in the rating classification presented. When we have come to an understanding in the use of Table IV and appreciate that luminaires providing an "A" rating should never be exceeded, then we can reclassify luminaires in this group as A1, A2, A3 and A4. But the first step must come from Table IV as now given. This does allow for compromises but narrows them down to reasonably good lighting installations. You cannot say to those who do not have a full appreciation of lighting that unless you do it my way (which is the right way) we will forget the matter and you can do it your way. This seems to be more of the form of Forcible Regimentation or dictatorship. While Mr. Logan talks about natural environment and perfect surrounding conditions, shall we say that a man who has lost a leg, arm or an eye shall be cast out of society and our work world? Not at all! There are many men and women with these handicaps who are serving remarkably well on jobs of great importance. There is no sharp demarcation in comfort of seeing and it still is in order to take an aspirin when you have a headache.

Dr. Spencer exposes some interesting data in connection with coefficient of utilization, comparing poor room conditions with ideal lighting and room conditions. Her example of luminous-indirect luminaires showing coefficients of utilization about 60% higher for ideal room conditions indicates the importance of high reflection factors of all surface finishes in a room. However, luminous-indirect lighting has no monopoly on the interreflection theory and applies equally as well to other luminaires analyzed in the paper. But in preparing a practical paper we must face existing conditions realistically and apply average values under these conditions to all the luminaires studied. As a typical example of this on a recent job, we found that a louver type luminaire was selected for relighting a large drafting and engineering office area. A complete analysis of the room was made with talented engineers and modern office practice was followed throughout. The entire area was refinished to the delight of an illuminating engineer's dream. A metal acoustical ceiling was installed, all windows covered with venetian blinds, new flooring applied, all new furniture supplied including drafting tables and desks with light "mist green" surfaces. The cost of this job is estimated at about $200,000.00. The luminaires supplied were of a luminous-indirect type and they alone represented about 10% of the total cost, which was over 50% higher in cost than the louver type luminaires originally considered. This is our job in recommending "seeing" not just lighting. Again, this is a special case and by no means the "average." We can always adjust our calculations to conditions which warrant it. Dr. Spencer is concerned about maintenance factors and so are we all. However, we have never been able to duplicate in our tests such maintenance factors as she indicates under average operating conditions. It seems futile to exchange opinions on this subject but a carefully controlled test in Texas classrooms disclosed that a two-lamp louvered installation depreciated 6.4 per cent in six months while a two-lamp luminous-indirect installation depreciated at 35.7 per cent in the same time. In spite of this, let me agree with Dr. Spencer this is one task, mighty in scope, that our Society should tackle as an assigned research problem. Then

it will be unnecessary to exchange individual opinions. How it is possible to get a maintenance factor for a luminous ceiling of 87 per cent is very difficult to understand. Lamp manufacturers have published data on lamps which shows that the light output may depreciate 25 to 35 per cent on the average for average operating conditions by the end of rated life. The light output during life averages approximately 80 per cent of the 100-hour value. So the average depreciation of lamps alone drops the maintenance factor below that suggested by Dr. Spencer for luminous ceilings and does not leave room for dust and dirt depreciation. If we stick to average conditions, it is more reasonable to expect a consumption of closer to 4 watts per square foot for luminous-indirect lighting than under two watts per square foot, as suggested by Dr. Spencer, to provide a level of 50 footcandles. We are intrigued by the $2.00 per square foot cost for luminous ceilings for 50-footcandle installations. We would like to see contracted costs on such installations. Dr. Spencer in using the Moon-Spencer method of rating lighting systems would restrict luminaires only to the luminous-indirect type and to luminous ceilings. These systems also rate highly with the method used in this paper.

Messrs T. D. and G. P. Wakefield take a firm stand for luminous-indirect lighting with pot-shots at common "footcandle" installations. They would discount appearance of a room, a point which we find difficult to do with architects, engineers and owners. They belittle maintenance, tossing it off lightly as a janitor's job while most of us join the parade in beseeching users to keep luminaires clean and properly lamped. They take first cost and operating cost with a snap-of-the-finger attitude while we struggle to extend specifiers and users to give way in this connection. They do all this with a well respected view in mind by strongly advocating the use of "quality footcandles." Their stand on this point is an admirable one. Let us agree that they are correct in what they say. Surely the specifiers and users of lighting are not fully aware of this for if they were, would there be more lighting with louvered luminaires than with luminous-indirect? Would the percentage of all louvered installations in the country be as over-whelming as it is? My paper nevertheless narrows down the luminaires suitable for office lighting and rates luminous-indirect lighting as high favorite. Until such time as definite proof is available that one-third less footcandles (34 ft-c) with luminous-indirect lighting is equal to 50 footcandles of other types of lighting, we hesitate to accept this assumption. On this basis, we can not accept the cost comparison presented. Neither is it reasonable to increase the room reflectances for luminous-indirect luminaires and neglect the same conditions for louvered luminaires.

Mr. Neidhart considers that the paper, as presented, should be viewed with certain limitations. We appreciate his concluding remarks in stating that the paper is a "...logical approach to a difficult problem ..." for this is what was in mind when the paper was written. It is true that additional luminaires might have been included, one of which, as Mr. Neidhart suggests, is a four-lamp luminous-indirect unit. This unit was not considered as an existing popular-type commonly-used luminaire. For an intelligent analysis of this type of unit, an accurate study would be required. It appears, however, with a ten-foot ceiling in a large room that luminaires would be spaced in rows ten feet apart to keep costs down to a reasonable range. On such an arrangement the luminaires would necessarily have to be suspended low for good ceiling brightness coverage and reasonable uniformity of illumination. Luminaires probably would be less than 8 feet above the floor. If the units were mounted closer to the ceiling the comfort rating would drop due to brightness concentration on the ceiling immediately above the luminaires. Mr. Neidhart comments on economic costs of two-lamp versus four-lamp luminaires. Our study revealed that to provide uniform illumination levels under the conditions given four-lamp luminaires would be installed as individual units on individual outlets, or, at most, two four-lamp units per outlet. This raised the cost of mounting and wiring as shown in Table II, Series III. Luminaire costs may be lower as shown in the Table. If a selection is to be made between 2- and 4-lamp luminaires a closer study can be made following the method employed in Table II. It is doubtful whether a 4-lamp luminaire installation will prove as favorable in comfort rating as a 2-lamp luminaire installation. Mr. Neidhart mentions the use of higher maintenance factors than shown in the I.E.S. Handbook. Perhaps this is due to the fact that he is incorrectly applying luminaire designs with those shown in the Handbook. Again, there is the question of "limitations" of types of luminaires shown for application below the ceiling. It will be noted that Troffer maintenance factors do agree with the few Troffers illustrated in the Handbook. The question raised about comfort rating of Systems #1, 2, 10 and 18 is answered in this rebuttal to other discussors.

Mr. Oetting brings out the fact that amortization costs will vary with organizations in assigning depreciation values. Since different concerns do vary in this phase of lighting cost from ignoring amortization to assigned values up to and over 20%, this part of the analysis is of least importance in operating costs. However, any adjustment from the values shown may be made to agree with local conditions. The figures given, at least, are relative and present a pattern of costs for the various systems studied. Mr. Oetting in referring to the maintenance factors used in the paper states "... the author is forced to travel the uncertain road of assumption." Yet, his only offering to the "D" rating assigned to System #17 and #18 is that "... this is at variance with the *opinion* of many users of these types ..." To what extent is this at variance, and "opinions," are of little help without facts. Typical of Mr. Oetting's careful consideration and wisdom in maintenance problems, he very wisely ends the above quoted sentence with "... and points up the need for comparative data under identical or quantatively identified atmosphere conditions." We agree wholeheartedly with this statement and again refer to the advisability of proposing this as an important I.E.S. research project.

Mr. Barr stands in defense of publishing articles of practical value in ILLUMINATING ENGINEERING. His comments are highly encouraging and very much appreciated for as a lighting engineer in a utility company he has found the need for recommending lighting installations to satisfy the desires of clients, as well as management. Mr. Barr asks if lamp life for the 40-watt T-17 lamp might be considered at 7500 hours rather than 6000 hours. We have followed the values of lamp life specified by lamp manufacturers, but must admit that these manufacturers do not always agree on lamp life and lumen output. About group replacement? By all means, this practice leads to surprising economy when weighed in terms of the cost of light. We have tried to answer all questions raised by discussors but need we say more than has already been said about maintenance?

As a specifier and installer of good lighting, we welcome Mr. Osborn's comments. His encouraging remarks reflect his great desire for a change in thinking from "how much

does it cost?'' to ''how much can I get for the cost?'' The author again wishes to acknowledge that before and during the time this paper was written, Mr. Osborn's feeling in this regard was highly inspiring at all times.

It is gratifying to have a lighting consultant, such as Mr. Kelly, emphasize the importance of orientation of luminaires for greatest comfort. This is a point very often overlooked and sometimes results in a very uncomfortable lighting job, whereas if office workers ''faced'' the installed luminaires properly the lighting might well be quite comfortable.

Mr. Zahour agrees that slimline lamp installations run around 10% higher than standard type fluorescent lamps. We agree with him that there is a trend toward the use of slimline lamps. The trend, however, is very gradual and not one that appears to put standard fluorescent lamps ''out of business'' for some time to come.

The mere fact that prominent men, associated in the lighting profession for many years, like Mr. Booth and Mr. Kinney, have reviewed my paper and take of their busy time to submit comments can only be fully appreciated by the author.

When it comes to ''ceilings'' Mr. Washburn's problems of durability, efficiency, comfort, maintenance, etc., seem to coincide with those of lighting. His general comments will be of interest to members of our Society and we invite such comments at all times from our allies in the lighting profession.

Mr. Meaker reminds us that the glare ratings given are for one set of conditions based on 10-foot ceilings. These conditions are not too far-fetched because they are what architects propose in the design of modern office buildings. ''Watch out for costs,'' say the architect, ''with higher ceilings.'' Sometimes he even favors a lower ceiling (Heaven forbid). Glare factors would be slightly higher for ceilings a foot lower and slightly lower for ceilings a foot higher. Mr. Meaker takes an admirable stand in referring to Mr. Guth's BCD studies. We agree with this thinking but in the meantime, let's stop the ''guess factor'' and use the ''glare factor'' until something better and more generally practical comes along.

The author wishes to thank all those who participated in discussing this paper. The vast amount of interest shown, whether in agreement or of a controversial nature, indicates the continued need of the practical approach to our lighting problems to supplement and augment the scientific studies carried on by our Society.

Lighting a Super Gas Station

A variety of lighting techniques are used to provide an effective brightness pattern in Clark's Super Gas Station, Milwaukee. Pairs of 1000-watt flood units (inset photo lower right) mounted high at the pump islands, and the pitched ceiling that extends beyond the show windows and entrance, serve to concentrate attention at outdoor and indoor sales area. The bulletins are lighted by 200-watt filament lamps on 4-ft. centers.

The combination of two 1000-watt floodlights (one pointed toward the highway, the other toward the station), four 40-watt Cool White fluorescent lamps in each pylon, and 200-watt filament lamps in the pump globes, provides 25 footcandles between the pylons and 5 footcandles between pump islands. Rows of slimline fluorescents, consisting each of a 72" and a 48" T-12 lamp inside and a 48" lamp outside under the canopy are spaced on 3-foot centers. The resulting illumination is 80 footcandles inside the station and about 40 footcandles under the canopy. Photo courtesy of General Electric Company, Cleveland, Ohio.

I.E.S. Guide for the

Photometric Testing of Floodlights of 10 to 160 Degrees Total Beam Spread

Prepared by the Committee on Testing Procedures for Illumination Characteristics of the Illuminating Engineering Society*

Foreword

The following report represents a revision of two former I.E.S. publications: "Testing Specifications for Lighting Equipment, Section II, Narrow Beam Enclosed Projectors" (1936) and "Specifications for Testing Lighting Equipment, Section II, Specification No. F-2-1941, Incandescent Filament Floodlights" (1941).

COMMITTEE ON TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS

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1. Objective

(a) To provide a guide that will promote uniform test results in determining and reporting the illumination characteristics of floodlights of ten to 160 degrees total beam spread,** utilizing both electric filament and electric discharge lamps.

(b) To provide data useful for evaluating floodlights, the illumination characteristics are described in terms of beam candlepower distribution, beam lumens and beam spread.

2. Selection of Floodlights

Floodlights selected for test should be representative of the manufacturer's regular product.

3. Electrical Supply (Regulation of Line Voltage)

The supply should not vary more than ±½ per cent in voltage during test.

4. Test Apparatus

4.1—*Test Lamps*—Test lamps should be selected for close conformance to manufacturers' design dimensions and construction and seasoned in accordance with Appendix A. To insure stable lamp performance, electric filament lamps should preferably be operated at a constant current corresponding to approximately 75 per cent of rated lumen output. Mercury vapor lamps should be operated at constant rated lamp watts while sodium vapor and other lamps should be maintained at rated lamp current.

4.2—*Photometric Equipment* — The photometric equipment should be calibrated throughout the entire usable scale and the individual readings should be reproducible within a tolerance of ±2 per cent. Provisions should be made for correct optical positioning of the floodlights in relation to the photometer axis and for candlepower measurement at any angular setting in both horizontal and vertical directions. Provisions should be made for eliminating stray light from the test setup.

4.2.1—*Photometric Integrator**1 — To average out minor variations in the beam, an integrating device should be used which will integrate the illumination over one square degree (20.94 inches x 20.94 inches for 100-foot testing range) or over a circular area of 20.94 inches in diameter at a distance of 100 feet. See Appendix B.

4.2.2—*Testing Distance* — Common practice is to use a 100-foot test distance; the dimensions of the photometric integrator given above are for this distance.

4.3—*Electrical Instruments*—The instruments used should have a good reproducibility of indication and give a large scale deflection for conditions under which they are used. Each meter should be free from frictional and/or heating errors. The accuracy of the meter needed depends upon the method of test used (see "Methods" paragraph 5.1).

5. Test Procedure

5.1—*Methods* — Those generally employed in photometric testing are the Relative Method and the Direct Method. The Relative Method depends upon operating the test lamp in accordance with paragraph 4.1, without determining the absolute lumen output of the test lamp or the absolute candlepower when the test lamp is used in the floodlight. After the relative lumen output of the test lamp is calculated and the relative candlepower of the beam is measured, the final candlepower of the beam is obtained by prorating the relative values to the manufacturer's rated lumen output for the type of test lamp used. The Direct Method depends upon calibration of the test lamp in terms of lumen output and calibration of the photometer in terms of candlepower measured so that the readings from the floodlight tested will be directly in terms of candlepower. The following instructions should be fol-

*Approved by the I.E.S. Council, October 1950.

**For the photometric testing of floodlights having total beam spread of ten degrees or less, see National Electrical Manufacturers Association Approved Standard "FL8-10 NEMA Photometric Testing Procedure for Searchlights." A floodlight which has a total beam spread of 160 degrees or more may be tested as if it were a direct type of luminaire for general lighting. A floodlight may be tested by measuring the illumination on a plane in a specified relation to the floodlight. Users may desire such a test since it avoids calculations of illumination from beam candlepower values.

*Optional with floodlights utilizing electric discharge lamps, since there would be no filament images.

lowed to aid in consistent results.

5.1.1—*Relative Method*—**(a)** The relative candlepower readings of the test lamp alone and of the lamp-floodlight combination should be made with the test lamp operating under identical electrical conditions in both tests.

(b) The test lamp's average candlepower may be measured at each angular setting by rotating[2,3] the lamp or by taking the average candlepower values in not less than 10 planes spaced equally around the lamp. The relative lumen output of the test lamp alone is obtained by the usual summation process using zonal lumen constants.

(c) All candlepower readings should be corrected in proportion to the rated lumens of the test lamp by multiplying by the ratio of the rated lamp lumens to relative lamp lumens. For selection of angles for floodlight photometric measurements see Section 6.

5.1.2—*Direct Method*—**(a)** In this method, both the test lamp and photometer should be calibrated against photometric standards.*

(b) The test lamp should be calibrated in an integrating sphere under the same electrical operating conditions as those used in testing the floodlight. Lamp current or wattage (depending upon type of source, see paragraph 4.1) should be checked with a calibrated meter with a reproducibility of ±0.25 per cent. The selected current or wattage should be held constant throughout the test.

(c) The photometer, whether of photoelectric or visual type, should be calibrated against a candlepower standard.

(d) The floodlight candlepower distribution should be read with a calibrated test lamp and a calibrated photometer. Since the electric filament lamp is operated at approximately 75 per cent of its rated lumens, both during calibration and test, all photometric readings should be corrected to candlepower at rated lumens of the test lamp by multiplying the readings by the ratio of rated lamp lumens to calibrated lamp lumens. With electric discharge lamps, correction to rated lumens is also necessary since these lamps are operated at a measured light output corresponding to rated watts (mercury) or rated current (sodium).

*A lumen or candlepower standard is a light source which has been calibrated by a recognized standardizing laboratory as to lumen output and/or candlepower in a given direction.

PHOTOMETRIC TEST REPORT

EQUIPMENT TESTED

TYPE Westinghouse 1500 Watt PAR-38 Floodlight

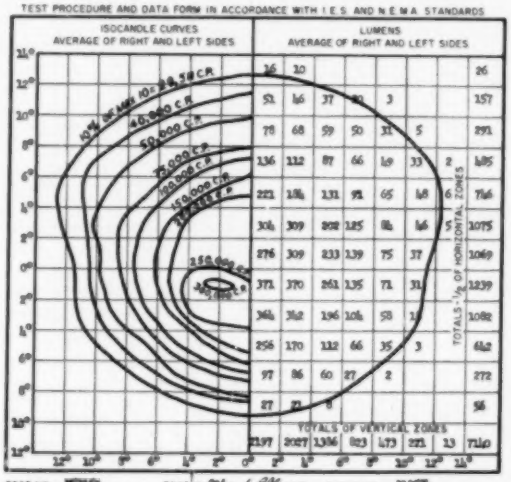
REFLECTOR Front Section Parabolic, Center & Rear Sections Spherical

AUX. REFLECTOR Specular Alzak Aluminum

COVER GLASS Clear, Colorless, Plain

NOMINAL LAMP DATA				TEST RESULTS	
WATTS 1500	FILA. TYPE C-7A			AVE. MAX. CANDLEPOWER 225,110	
VOLTS 110	FILA. HEIGHT Nom.	Actual		BEAM LUMENS 1,4,290	
BULB PS-52	FILA. WIDTH 2362	2248		BEAM EFFICIENCY 40.6%	
BASE Mogul Screw	LUMENS 33,500			HOR. BEAM SPREAD 25°	
SERVICE General				VERT. BEAM SPREAD 22°	
LIGHT CENTER LENGTH 3-1/2"				Max. Candlepower 306,200	

TEST PROCEDURE AND DATA FORM IN ACCORDANCE WITH I.E.S. AND N.E.M.A. STANDARDS



TEST NO. 1500150 TEST BY [illegible] CURVE NO. 31,355

APPROVED [illegible] DATE Sept. 25, 1967

Figure 1. Typical test report.

5.2—***Mounting of Floodlights.***—The floodlight should be mounted on an altazimuth (goniometer) device to allow positioning to definite angles about both horizontal and vertical axes. The center of the aperture should be at the intersection of the horizontal and vertical axes.

5.3—***Cleaning of Optical Parts***—All glass, reflectors, and other optical parts should be thoroughly cleaned before candlepower measurements are made. However, no special cleaning should be effected if the test is for maintenance purposes.

6. Selection of Angles for Photometric Measurements

6.1—***General***—The method of taking candlepower readings is to traverse the beam with such spacings as to give approximately 100 reading stations uniformly spaced throughout the beam. The limit of the beam is to be taken as 10 per cent of the average of the ten highest candlepower values recorded in this prescribed exploration of the beam (see Appendix D).*

6.2—***Stray Light***—**(a)**—The outside of the beam may also be divided into suitable rectangular areas of larger dimensions[4] (see Appendix E, paragraph E-1), or

(b) Additional readings may also be taken to obtain the candlepower values along eight equally spaced radial lines carried out to the extreme angular range of the stray light.[5] (See Appendix E, paragraph E-2.)

7. Computation of Test Results

The process of developing useful results involves the following steps:

(1) Averaging corresponding candlepower values in the right and left sides of the beam.

(2) Plotting the change of candlepower across each of the horizontal traverses in the beam and working out from these data the isocandle and the beam limit curves.

*Readings on the horizontal and vertical axes are not included in the prescribed exploration.

(3) Computing the lumens in each individual test area or rectangle using the proper lumen constants from Appendix F.

(4) Summing the lumens of each individual test area, making suitable allowance where a test area lies partially within the beam and partially in the stray light zone.

(5) Computation of stray light—(optional) (see Appendix E).

(6) Computing beam efficiency of floodlight by dividing beam lumens by manufacturer's rated lumen output of test lamp.

(7) Computing over-all efficiency (optional) by dividing total lumen output (sum of beam lumens and stray light lumens) by manufacturer's rated lumen output of test lamp.

8. Test Report

Test results (see Fig. 1) should include:

(1) Floodlight description — Manufacturer's name, type, and catalog number. Reflector shape, material, manufacturer's designation, and dimensions. Cover glass or lens (if used) manufacturer's designation, shape, optical character of surface, dimensions, auxiliary reflecting devices (if used). Other essential information, including method of selection of sample. A sketch showing above relationships is helpful.

(2) Lamp description—Type, service and designation. Rating — watts, lumens, volts or amperes. Bulb, base, normal burning position. Dimensions —light center length, filament construction, nominal* and actual light source dimensions. Light center position during test.

(3) Maximum beam candlepower and average maximum candlepower.

(4) Beam spread in degrees in both vertical and horizontal directions.

(5) Isocandle curves, average of right and left sides in the beam.

(6) Average lumen distribution in the beam.

(7) Beam lumens.

(8) Total lumens, i.e., beam lumens plus stray light (optional).

(9) Beam efficiency.

(10) Total efficiency (optional).

(11) Test distance.

(12) Note of any modification in the preceding suggested method.

*Optional, but useful in estimating variation in beam width in specular reflectors.

Appendix A
Seasoning Schedules for Lamps

A-1—All filament lamps which are to be photometered should be burned first as indicated in the seasoning schedules below:

Large Vacuum Lamps

Watts	Volts	Fils. Const.	Design Life (hours)	Seasoning Min.	Seasoning % Volts
Any	Any	S	0-1399	45	115
		S	1400 and above	60	115
		C	0-500	30	115
		C	501-999	45	115
		C	1000-1999	60	115
		C	2000 and above	60	120

Large Gas-Filled Lamps

Any	Any	C	0-15	15	100
Any	Any	C	16-99	30	100
Any	Any	C	100-200	45	100
Any	Any	C	300	45	105
Any (Except 1000W-30V)		C	500	45	110
Any	Any	C	750	45	110
0-200	Any	C	800	45	115
201-299	Any	C	800	60	115
300-2000	Any	C	800	90	115
0-74	Any	C	1000	45	115
75-150	32	C	1000	90	115
75-200	100-250	C	1000	45	115
300-2500	Any	C	1000	90	115
Any	Any	C	1350	60	115
Any	Any	C	1500	60	115
Any	Any	C	2000	60	120
900W Proj.	32	C	100	45	100% Amps
Series (All Types)		C	2000	240	108% Amps
1000	30	C	500	120 240	105 106
Series Gr. Replacement (All Types)		C		240	112% Amps

A-2—The seasoning schedule for a new lamp type should be similar to the listed type which, in regard to design life, most closely agrees with the new lamp even though the two have not the same service classification. In case of doubt, use that schedule which gives the longest period of seasoning — it is preferable to over rather than under season a lamp.

A-3—The above schedule applies to commercial photometry only. Where lamps are to be used as photometric standards, a 1000-hour life lamp should be burned at rated volts for 24 hours, and shorter life lamps should be burned for a similar per cent of their rated life.

A-4—Standard seasoning practice for mercury vapor lamps is to burn them 200 hours at rated watts, and for sodium lamps 200 hours at rated current.

Appendix B

B-1—As a general rule, electric filament floodlight beams are inclined to be uneven in intensity. Traces of filament images are nearly always visible and, unless care is taken in the photometric exploration, will cause individual readings to be either too high or too low, depending upon the extent to which the images fall upon the photometric device. If the photometric observation is made to cover too small an area, these filament images may cause erratic results which are difficult to reconcile with the rest of the data. For this reason an integrating device should be used which will integrate the illumination preferably over one square degree (20.94 inches x 20.94 inches for a 100-foot testing range).[1] This method of measuring candlepower values averages out minor variations in the one-degree beam segment and makes possible the obtaining of less variable and, therefore, more readily duplicable data.

B-2—In the case of floodlights utilizing electric discharge lamps there will be no filament images, and it is permissible to use photocells only, without the integrating device.

Appendix C
Calibration of Lamp and Photometer

C-1—***Calibration of Lamp (Relative Method)***

C-1.1—*For Current at Rated Lumen Output*

C-1.1.1—An acceptable lamp of the desired size and service should be seasoned and calibrated for current at rated lumen output, and also calibrated for intensity in a horizontal direction, as indicated by

permanent markings (fiducial lines) placed on the bulb.

C-1.1.2—The calibration of the lamp for current may be done in the integrating photometric sphere against photometric standards of luminous flux which have been calibrated by a recognized standardizing laboratory.

C-1.1.3—The calibration of the lamp for candlepower in a horizontal direction may be conveniently done on a bar photometer against standards of luminous intensity which have been calibrated by a recognized standardizing laboratory. The lamp should be held at the same current as found in the method of the preceding paragraph. When calibrating the lamp for luminous intensity, it is desirable to select a point at which the candlepower does not change for small changes in the positioning of the lamp. Slight misalignment of the lamp when calibrating the photometric integrator will then be of little consequence.

C-1.2—*For Current at 75% Lumen Output*

C-1.2.1—The test lamp may also be calibrated by rotating it at proper speed[2, 3] on a distribution photometer, and taking photometric readings at 10 degree vertical intervals (5, 15, 25, 35 degrees, etc.) about the lamp. Readings should also be taken at 0, 90 and 180 degrees from nadir. After these "relative candlepower" measurements are made on the bare test lamp, the "relative lamp lumens" may be calculated by applying the proper annular lumen constants (Appendix F, Table F-3) and the usual summation process. The final candlepower factor is then obtained by prorating the relative values to the manufacturer's rated lumen output for the lamp being used. The average horizontal candlepower of the lamp may now be evaluated. The rotation of the lamp is then stopped at such place that the stationary horizontal candlepower of the lamp is equal to the average rotating horizontal candlepower and the fiducial marks applied. During this test, the lamp current should be held to a value equivalent to approximately 75 per cent of the rated lumen output of the lamp to insure stable lamp operation.

C-1.2.2—The light output of gas-filled electric filament lamps is the same whether rotating or stationary, providing the lamp current is held constant rather than the voltage. The light output will be slightly different for different burning positions, however.

C-1.2.3—Instead of rotating the lamp as described above it is permissible to take stationary readings about the lamp providing sufficient vertical planes are taken to arrive at the proper average values.

C-1.3—*Results*

C-1.3.1—The calibration of the lamp then consists of three items:

Rated light output in lumens
Fiducial intensity in candlepower
Input in amperes and volts

C-1.3.2—It will be noted that having the fiducial intensity in candlepower and the rated output in lumens, the numerical ratio between the total bare lamp output in lumens and the intensity in the marked direction can be calculated. The fact that this numerical ratio is independent of the current or voltage at which the lamp is held is the basis of the following method for obtaining the floodlight illumination values. Of course, the lamp can be used as an absolute standard of intensity, but for the purpose of these tests it is better to use it as a combined standard and test lamp. The lamp is held at some definite current value instead of voltage value throughout the test, which further eliminates possible errors due to socket drop or faulty electrical connections.

C-2—***Calibration of Photometer***

C-2.1—The value for the test lamp obtained by the methods described above is now used to calibrate the photometer to be used to test the floodlight. Since the intensity of the standard lamp in the marked direction is a fixed numerical ratio to the total output of the lamp in lumens, regardless of the current at which the lamp is held, it is possible to calibrate the photometer by light received from the bare lamp in the marked direction, as though the lamp were operated at rated intensity. Since the lamp is held at the same current throughout the standardization and test, floodlight illumination values will be determined which will be the same as if the lamp were held at rated lumen output throughout the test.

C-2.2—For this purpose any ammeter of good constancy and giving large scale deflection for the current to be measured is satisfactory. The exact meter calibration need not be known. In general it is best to hold the current as per paragraph 4.1 of the text in order to insure minimum change of light output from the lamp during the test. However, the selected current must be carefully maintained throughout the test. By calibrating the photometer directly against the test lamp, regardless of the exact candlepower at which the lamp is held, floodlight illumination values are obtained in terms of the standardization values of the lamp.

C-2.3—The standard lamp is placed at the test distance (100 feet) from the floodlight integrator so that the illumination received is that established by the fiducial lines on the bulb. In this manner the photometer may be calibrated directly in candlepower per scale division. While the light output and beam intensities under these conditions will be, in general, less than the actual output intensities of the lamp at normal rating, this method of calibrating the photometer exactly compensates for this difference, so that the photometer readings times the candlepower per scale division factor are correct.

C-2.4—The photometer may also be calibrated by the Direct Method (see paragraph 5.1.2 of text).

Appendix D

Procedure for Making Photometric Observations

D-1—The test lamp is adjusted in the floodlight, connected with the same ammeter of Appendix C, paragraph C-2.2, and the test carried on at the selected current.

D-2—In general, the focusing of the lamp in the floodlight is to be done at a distance of 100 feet or more from the observing screen, and should preferably be done at the same distance at which the photometer readings are made. For floodlights utilizing electric filament lamps, in order to have a definite location of the light source (filament) lamps for base-up or base-down burning should be set in the floodlight with the lead wires away from the principal optical element. For lamps which burn in the horizontal position, the lead wires should be placed uppermost.

D-3—The lamp should be adjusted in the floodlight to give the narrowest uniform and symmetrical beam. The determination of reference lines for the beam can be made visually when feasible. In many cases it will be necessary to determine reference lines by establishing the vertical and horizontal limits of the beam photometrically. The intersecting lines halfway between these limits will constitute the reference lines. For non-focusing types of floodlights lamps should be centered visually in the floodlights, and to insure correct positioning lamps of the correct light center length must be used.

D-4—As a suggested method, the exploration of the horizontal and vertical axes to the limits of stray light should be made first, followed by horizontal traverses at the various vertical angles to include the limits of the beam, and then followed by the remaining exploration (optional) of the total lighted area. This method of exploration permits checking frequently at zero degrees, which will eliminate the possibility of error due to possible change in the lamp during the test. This method of taking readings insures complete information as to beam

_____ FLOODLIGHT PROJECTOR

RENDERED TO _____

REFLECTOR: Shape - Front section parabolic, center section spherical, rear section parabolic.
Material - Mirrored glass
Diameter - 19 inches

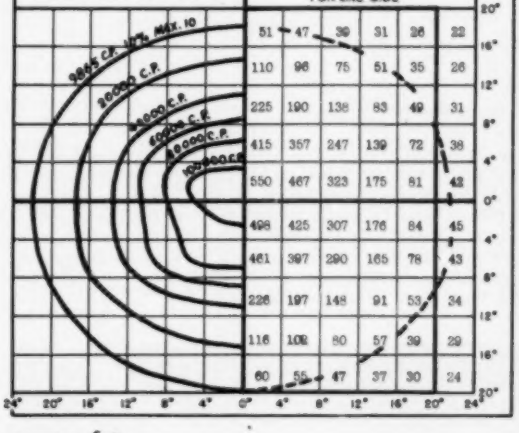
COVER GLASS: Lightly stippled lens.

LAMP: 1500 Watts; 115 Volts; 33000 Lumens; PS52 Clear Gas-Filled Bulb; C7A Filament; Mogul Base; General Service. Filament dimensions - 25.8 mm. high x 34.9 mm. wide. Light center length - 9-1/2 inches.

PROJECTOR DATA

TOTAL LUMENS	- 25650
TOTAL EFFICIENCY	- 77.5%
BEAM LUMENS	- 15990
BEAM EFFICIENCY	- 48.5%
BEAM SPREAD VERTICAL	- 36.5°
BEAM SPREAD HORIZONTAL	- 44°
MAXIMUM BEAM CANDLEPOWER	- 117000

AVERAGE ISOCANDLE CURVES



AVERAGE LUMEN DISTRIBUTION FOR ONE SIDE

51	47	39	31	26	22	20°
110	96	75	51	35	26	16°
225	190	136	83	49	31	12°
415	357	247	139	72	38	8°
550	467	323	175	81	42	4°
498	425	307	176	84	45	0°
461	397	290	165	78	43	4°
226	197	148	91	53	34	8°
116	102	80	57	39	29	12°
60	55	47	37	30	24	16°
						20°

TOTAL LUMEN DISTRIBUTION (AVERAGE FOR ONE SIDE)

15	13	11	9	7	4	2	70°
42	37	29	17	10	5	3	60°
73	72	67	47	22	7	3	50°
95	91	85	76	44	13	4	40°
128	116	101	89	63	23	5	30°
4072		137	100	76	34	5	20°
		191	105	80	38	6	10°
4319		191	108	80	40	7	0°
		149	100	78	34	6	10°
178	146	117	90	59	22	4	20°
124	111	99	75	38	12	3	30°
91	85	70	41	18	6	2	40°
42	36	24	13	7	4	2	50°
8	8	6	5	4	3	1	60°
							70°
0°	10°	20°	30°	40°	50°	60°	70°

CANDLEPOWER DISTRIBUTION THROUGH AXIS

ANGLES	HORIZONTAL PLANE	VERTICAL PLANE
75°	164 L	136
65°	525	308
55°	2100	1290
45°	3600	2450
35°	4330	3200
25°	7000	4350
15°	33800	19000
5°	107000	93000
0°	117000	117000
5°	104000 R	94000
15°	35000	20100
25°	7300	5900
35°	4480	4180
45°	3900	3000
55°	2350	1340
65°	540	388
75°	185	134

PLOTTED BY: Em J.
COMPUTED BY: Em J.
CHECKED BY: [illegible]
DATE: [illegible]

Figure 2. Typical form for report showing stray light.

characteristics, and also gives sufficient data to evaluate the distribution of stray light from the floodlight.

D-5—After the approximate degree limits for the beam have been determined, the spacing for the reading stations is laid out so that approximately 100 photometric readings may be made throughout the beam. Spherical lumen constants are given for spacings from 1 degree x 1 degree to 10 degree x 10 degree (see Appendix F). By a proper selection of these areas, any size of beam may be explored by about 100 equal spacings.

D-6—In the case of floodlights utilizing electric discharge lamps which must be operated in the vertical position only,[6] it is permissible to mount the floodlight on a distribution photometer[7] with the lamp axis vertical, and since there are no filament images, photocells may be used in lieu of the integrator. An appropriate test distance should be used.

Appendix E

Computation of Stray Light

E-1—The outside of the beam is divided into appropriately equal rectangular areas of larger dimensions than the spacings within the beam (usually 10 degrees).[4] The typical report of Figure 2 illustrates the method used for evaluating the stray light. This method is applicable to all beam formations and is the most accurate.

E-2—The following method lends itself to beams that are circular in cross section:

Photometric readings are taken along eight equally spaced radial lines carried out to the extreme angular range of the stray light. Four of these radial lines may be the regular horizontal and vertical axes. The remaining four radial lines are taken at 45 degrees to these horizontal and optical axes. For radial traverses which are in between the vertical and horizontal axes, Table F-2 gives the correct degree settings to take care of the fact that the settings for these angles cannot be read directly on the horizontal and vertical angular traversing scales. The photometer readings corresponding to the same degree settings of all the radial traverses are averaged except those which are within the beam itself. The average lumens in these annular zones are computed from F-3.

Appendix F

Table F-1—Constants for the conversion of candles into lumens for rectangular zones. (Spacings up to 10° x 10° published in Illuminating Engineering, June 1941, pages 675-686.)

Spacing 15° Vertical x 15° Horizontal
Vertical Settings of 0°, 7.5°, 22.5°, etc. for each.

Horizontal Settings of 0°, 7.5°, 22.5°, etc.

Horizontal Angle	K	Horizontal Angle	K
7.5	.06781	52.5	.04163
22.5	.06309	67.5	.02618
37.5	.05419	82.5	.008901

Table F-2—Relation of angles (r) on radial lines to horizontal (h) and vertical (v) angles. (Published in *I.E.S. Transactions*, June 1933, page 509.)

Table F-3—Constants for the conversion of candles into lumens for annular zones. (5° and 10° zones published in ILLUMINATING ENGINEERING, July 1949, page 419. 5° zones with 0° at midzone published in *I.E.S. Transactions*, June 1933, page 511.)

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4. "Testing Procedure for Narrow Beam Enclosed Projectors," *Trans. I.E.S.*, Vol. 31, p. 508 (May 1936).

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7. Horton, G. A.: "Modern Photometry of Street Lighting Luminaires," ILLUMINATING ENGINEERING, Vol. XLIII, p. 1044 (November 1948).

8. Rose, S. L. E.: "Photometric Tests of Floodlighting Projectors," *G. E. Rev.*, Vol. XX, No. 9, pp. 743-748 (September 1917).

9. "General Procedure for Photometry of Incandescent Floodlights," *Proc. Assoc. of Railway Electrical Engineers*, Vol. 18, p. 133 (1927).

10. "Incandescent Floodlight Testing Procedure — Revision of A.R.E.E. Specifications," *National Electric Light Association Lighting Service Manual, Part III* (August 1928).

11. "Specifications for Testing Lighting Equipment, Section II, Specification No. F-2-1941, Incandescent Filament Floodlights," ILLUMINATING ENGINEERING, Vol. XXVI, No. 6, p. 671 (June 1941).

Increased Comfort in Industrial Lighting

The recent trend toward increased comfort in industrial lighting is well illustrated in the metal-spinning shop below, in which high level illumination is combined with well balanced brightnesses. Considerable upward light is supplied by the units; the luminaires are well shielded for protection against direct glare; room finishes are quite light in color, again helping to balance brightness. Walls are cement block, the floor is cement, and the ceiling is white. Continuous rows of louvered troffers suspended two feet from the ceiling provide 40 footcandles of illumination. The spacings are 10 feet and 11 feet, depending on work locations. Each unit is equipped with two 48T12 fluorescent lamps. Dimensions of this shop, that of Branhan, Mareck & Duepner Co., Minneapolis, Minn., are 100 feet by 85 feet, with a 13-foot ceiling. Photo courtesy of General Electric Lamp Dept., Nela Park, Cleveland, Ohio.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Summary of Action Taken at February Council Meeting, New York

Full attendance at the meeting of Council held February 8 at the Hotel Lexington, New York City, was curtailed somewhat by the "illness" of railroad switchmen. Proxies, and members of Council able to make the trip, brought the attendance to 26. Present were: President Walter Sturrock, presiding; S. G. Hibben and E. H. Strong, Vice-Presidents; A. H. Manwaring, General Secretary; Lee Tayler, Past-President; R. F. Hartenstein, Treasurer; Myrtle Fahsbender, Duncan Jones, Roy Palmer, Hoyt P. Steele, R. W. Staud as proxy for L. A. Hobbs, M. N. Waterman, proxy for R. L. Biesele, Jr., Directors; G. F. Dean, Jos. S. Schuchert, R. G. Slauer, F. C. Winkler, L. H. Graves proxy for F. A. Covington, C. C. Keller proxy for J. B. Browder, and C. B. Pederson proxy for C. N. Laupp, Regional Vice-Presidents; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director; C. E. Ellis, Advertising and Promotion Manager; Ruby Redford, Editor; W. C. Brown, E. C. Huerkamp and H. H. Magdsick.

In addition to the regular Council business, such as report on receipts, expenditures and financial status of the Society, approval of Minutes and discussion of items referred by the Council Executive Committee, etc., action was taken on a number of items brought up for Council discussion.

Washington Conference

A final budget for the National Technical Conference to be held in Washington, D. C. August 27-30, presented by R. F. Hartenstein was approved after full discussion.

H. P. Steele, Chairman of the Papers Committee, reported on the meeting of his committee during which outlines for 47 technical papers were tentatively accepted for presentation on the Conference program. Mr. Steele also outlined the programming schedule for the several sessions planned. His preliminary report indicated special sessions on street, aviation, residential lighting, sources, relation of I.E.S. to the Federal Government, special symposium on comfort and glare, and others.

Membership

The General Board of Examiners reported to Council the election of 74 Associate Members and 9 Student Members (lists of which are given at the end of the Telecast Section, this issue) and recommended for election 12 Members and two Members Emeritus, E. C. Crittenden and Richard E. Simpson. Favorable action on the report, together with other changes in membership results in the following membership statistics.

September 30, 1950		February 8, 1951
7057	Total Membership	7208
32	Members Emeritus	34*
41	Fellows	42
1610	Members	1654
5005	Associate Members	5159
369	Student Members	319

*Includes 11 Fellows of the Society.

Sustaining Membership

Favorable action of Council on the report of the Sustaining Membership Committee, C. C. Shotwell, Chairman elected:

Moe Light, Inc.
700 Oak Street
Fort Atkinson, Wisconsin
Official Representative: Stanley Warner

Efengee Electrical Supply Co.
671 W. Washington Blvd.
Chicago 6, Illinois
Official Representative: Lee Mirus

Electric Supply Corporation
701 W. Jackson Blvd.
Chicago 6, Illinois
Official Representative: L. B. Mangione

Publications Progress Report

An interim progress report of the Publications Committee was submitted by E. C. Huerkamp, Chairman. Production of the revised I.E.S. Lighting Handbook was reported advanced on eleven sections of a total of eighteen, with indications of progressing as scheduled toward completion of the new book by October 1st.

Reporting on the status of the journal, Mr. Huerkamp announced that Miss Ruby Redford had been named Editor of Illuminating Engineering on the recommendation of his Committee. Further report on the journal included plans for a special symposium on industrial lighting planned for the May issue, a report on savings in operation resulting from a study of various production expenses and a financial report at the four-months period.

Mr. Huerkamp also reported that a Membership Roster to be a business directory of I.E.S. Membership was being compiled by the Publications staff for early publication.

New Offices for HQ

A. H. Manwaring, General Secretary, requested Council's authorization to sign a lease for space at 1860 Broadway, to serve as Headquarters Offices of the Society as of May 1, 1951, some of the space to be sublet to two other tenants. Mr. Manwaring reported on the circumstances surrounding the matter, recommending favorable action. Authorization for the arrangements recommended was given.

No Medal in 1951

The annual report of the I.E.S. Medal Committee, submitted by G. W. Beals, Chairman, recommended that no award of the I.E.S. Gold Medal be made in 1951. It was the further recommendation of the Committee that the procedure governing the nomination of Medal candidates be changed, to provide that names, and names only, be submitted prior to January 1st, and not require that complete biographies accompany nominations. Their suggestion was that following a preliminary screening of names, headquarters would be asked to obtain biographies of the candidates to be further considered. The Committee was requested to write new rules for Medal nomination, to be submitted to the Committee on Policy and Procedure for study.

Public Relations

J. S. Schuchert, Chairman of Public Relations and Information, presented a progress report on this activity, indicating an active local organization is now in operation. He noted that each Section and Chapter has plans to devote one meeting during the year to the subject of information on the Society's work. A

booklet on I.E.S. objectives and benefits is available to local sections, and a newsletter on Society activities is underway, the first copy of which has already been distributed.

Industrial Lighting

The proposed American Standard of Industrial Lighting, as prepared by the I.E.S. Committee on Industrial Lighting as a complete revision of the 1942 Practice, was submitted by C. L. Crouch, Technical Director. After discussion of the report, previously circulated for Council study, the report was approved for letter ballot subject to written approval of all members of the Industrial Lighting Committee.

Testing Procedures

A proposed revision of the approved Specifications for Testing Lighting Equipment (published March 1940) to make the specification applicable to the photometric testing of concentric ring luminaires, was presented by C. L. Crouch, and approved by Council.

Technical Program

Progress of the Society's technical program was reported by S. G. Hibben and C. L. Crouch, indicating numerous technical committees actively working toward completion of study reports. Special studies on defense lighting are on the docket. Numerous requests from the government have been received requesting I.E.S. cooperation on emergency lighting, air raid shelters and similar subjects.

Next Council, Chicago

In adjourning the meeting, President Sturrock announced that the next meeting of the I.E.S. Council would be held at the Edgewater Beach Hotel, Chicago, Illinois, on Thursday, April 5, 1951.

Society Headquarters To Move May 1st

The I.E.S. headquarters will move May 1st to 1860 Broadway (61st Street), New York 23, N. Y. All correspondence with the Society's headquarters should be sent to this address about or after that date. Until then, the address is still 51 Madison Avenue, New York 10.

The move has been necessitated by the expansion of the New York Life Insurance Co., whose tenants I.E.S. has been since its move there in 1937. Headquarters itself has expanded, since 1937, from five employees to nearly twenty-five, crowding itself out of its original office space several-fold. The new quarters are expected to provide sufficient space for I.E.S. activities, and possibly for the I.C.I. Central Bureau as well.

LIGHTING CALENDAR

Society Events

March 22-24, 1951 — Pacific Northwest Regional Conference, Davenport Hotel, Spokane, Wash.

April 5, 1951 — Meeting of I.E.S. National Council, Edgewater Beach Hotel, Chicago, Ill.

April 9-10, 1951 — Southern Regional Conference, Atlantis Hotel, Miami Beach, Fla.

May 9-11, 1951 — Canadian Regional Conference, Chateau Frontenac, Quebec City, Que.

May 14, 1951 — Midwest Regional Conference, Des Moines, Iowa

May 24-25, 1951 — Great Lakes Regional Conference, Hotel Gibson, Cincinnati, Ohio

June 14, 1951 — Meeting of I.E.S. National Council, New York, N. Y.

August 27-30, 1951 — Illuminating Engineering Society, National Technical Conference, Hotel Shoreham, Washington, D. C.

September 9-13, 1952 — Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

March 13-15, 1951—National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

March 15-17, 1951 — Electrical Maintenance Engineers Association of Southern California, Fifth Annual Industrial Electrical Show, Spring Convention Hall, Los Angeles, Calif.

March 19-22, 1951 — The Institute of Radio Engineers National Convention, Waldorf-Astoria Hotel, New York, N. Y. Radio Engineering Show, Grand Central Palace, N. Y. C.

April 2-5, 1951 — The American Society of Mechanical Engineers, Spring Meeting, Hotel Biltmore, Atlanta, Ga.

April 2-5, 1951 — 17th Annual Sales Conference, Edison Electric Institute, Edgewater Beach Hotel, Chicago, Ill.

April 2-7, 1951 — Electric Association of Chicago Industrial Electrical Exposition, Hotel Sherman, Chicago, Ill.

April 3-6, 1951 — Greater New York Safety Council 21st Annual Safety Convention & Exposition, Hotels Statler and Governor Clinton, New York, N. Y.

April 4-6, 1951—Midwest Power Conference, Hotel Sherman, Chicago, Ill.

April 9-11, 1951 — The Electrochemical Society Inc., Convention, Wardman Park Hotel, Washington, D. C.

April 17-19, 1951 — American Society Mechanical Engineers Industries Division Conference, Lord Baltimore Hotel, Baltimore, Md.

April 23-25, 1951 — National Academy of Sciences, Washington, D. C.

April 30 - May 2, 1951 — Chamber of Commerce 39th Annual Meeting, Washington, D. C.

April 30 - May 2, 1951 — The Spring 1951 Convention of the Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

April 30 - May 4, 1951 — National Materials Handling Exposition, International Amphitheatre, Chicago, Ill.

May 7-11, 1951 — National Fire Protection Association, Annual Meeting, Hotel Statler, Detroit, Mich.

May 10-11, 1951 — Electrical Contractors Association, Annual Convention, Royal York Hotel, Toronto, Can.

May 17-19, 1951 — Public Utilities Advertising Association, Hotel New Yorker, New York, N. Y.

May 20-23, 1951 — National Office Management Association, Hotel Commodore, New York, N. Y.

Week of May 20th, 1951 — National Association of Electrical Distributors, Atlantic City, N. J.

May 27-30, 1951 — American Society of Refrigerating Engineers, 38th Spring Meeting, Hotel Statler, Detroit, Mich.

May 26 - June 8, 1951 — Canadian International Trade Fair, Toronto, Can.

June 4-7, 1951 — Edison Electric Institute, 19th Annual Convention, Denver, Colo.

June 5-16, 1951—British Plastics Exhibition and Convention, National Hall, Olympia, London, England.

June 11-15, 1951 — Second Annual Conference on Industrial Research, Columbia University, New York, N. Y.

June 11-15, 1951 — American Society Mechanical Engineers, Semi-Annual Meeting, Royal York Hotel, Toronto, Canada

June 18-20, 1951 — Annual Convention of the Canadian Electrical Association, St. Andrews, N. B.

June 25-29, 1951 — Summer General Meeting, American Institute of Electrical Engineers, Royal York Hotel, Toronto, Canada

June 25 - July 4, 1951 — International Commission on Illumination, Stockholm, Sweden

July 2-4, 1951 — The American Society of Heating & Ventilating Engineers, Semi-Annual Meeting, Portland, Oregon

September 11-20, 1951—Building Research Congress, London, England

September 25-28, 1951 — Fall Meeting, The American Society of Mechanical Engineers, Minneapolis, Minn.

October 8-12, 1951 — 39th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 9-12, 1951 — National Electrical Contractors Associations, Annual Convention, Shoreham Hotel, Washington, D. C.

October 15-19, 1951 — Fall 1951 Convention of the Society of Motion Picture and Television Engineers, Hollywood-Roosevelt Hotel, Hollywood, Calif.

November 12-15, 1951 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 28-30, 1951 — Annual Meeting, The American Society of Mechanical Engineers, Atlantic City, N. J.

Executive Committee Holds Meeting in New York

Several actions of interest were taken by the Council Executive Committee at its bi-monthly meeting January 11, held at Society headquarters. Present at the meeting were President Walter Sturrock, presiding; S. G. Hibben and E. M. Strong, Vice-Presidents; A. H. Manwaring, General Secretary; R. F. Hartenstein, Treasurer; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director; and C. E. Ellis, Promotion and Advertising Manager.

Membership

As part of its report on new members and other changes in membership, the General Board of Examiners initiated discussion on the status of members in the Armed Service. The subject was referred to the senior Vice-President and the General Secretary for study, for report and recommendation at the next Executive Committee meeting.

New Sustaining Member

On recommendation of C. C. Shotwell, Chairman of the Sustaining Membership Committee, action was taken to accept as Sustaining Member:

Unistrut Products Co.
1013 West Washington Blvd.
Chicago 7, Illinois
Official Representative: George W. Butler

Local Activities

Prof. E. M. Strong, Chairman of the Local Activities Committee reported on the excellent well-attended meeting of the committee held at headquarters, referring to a number of recommendations developing from the meeting's discussions.

Among other items, Prof. Strong reported his Committee's extensive discussion of the problem of securing direct representation for all of the Society's Sections at the meeting of the National Board of Nomination. On recommendation of his Committee, means of securing effective representation for the Society's membership was referred for study to the Committee on Procedures and Policies.

Favorable action was taken by the Executive Committee on the recommendation that suitable certificates be awarded to local and national officers of the Society to be available at cost. Action was also taken to refer to the Local Activities Committee for study and recommendation the proposal that plastic paper weights using the Society insignia be made available for award.

Prof. Strong reported on activity of the Mississippi Chapter involving the preparation of school lighting recommendations in the name of the Society. It was noted that satisfactory guidance to the Chapter in such a special activity was provided by Prof. Russel Putnam, Chairman of the National Committee on School Lighting.

Prof. Strong further referred to a communication from the Western New York Section indicating some interest among the members in a proposed local plan for group insurance. Action of the Executive Committee on this proposal was that sponsorship of group insurance plans not be an authorized special activity for Sections and Chapters, and that the national Society not become involved in such a plan.

Other items of Prof. Strong's report indicated that: Steps are being taken to put into effect the Training Program for Section and Chapter officers recommended by the 1949-50 Public Relations and Information Committee.

The Rating System for Sections and Chapters recommended by the Public Relations Committee was not considered by the Local Activities Committee to be appropriate for developing the Society's Sections and Chapters.

New Regional Divisions are still under study; several Regional Vice-Presidents are recording the situation as they find it in the respective Regions for report to Mr. Hibben and Prof. Strong.

Defense Coordinating Committee

A. F. Wakefield, Co-Chairman, referred to the enlarged technical membership of the committee, the re-definition of the committee's scope toward specifically military objectives, and outlined the draft 1950-51 committee program now being circulated to committee members, as follows:

1. *Washington National Technical Conference.* Papers and authors to be suggested to Papers Committee.
2. *Task Committee #2.* Encouragement and assistance incident to the Task Committee under the direction of the Chairman, Dr. L. M. Bach, of Tulane University.
3. *Talent Survey.* Acknowledgment of the value of the talent survey recently completed by the Publications Office as an instrument of service to this committee.
4. *Joint Section and Chapter Meetings.* Encouragement of joint meetings with local posts of the Society of Military Affairs.
5. *Committee Meeting.* To be arranged at Fort Belvoir in cooperation with a member of the committee — Col. O. P. Cleaver.
6. *Defense Department Heads.* To be re-contacted in connection with the service of the Society to the Defense Program.
7. *National Security Resources Board.* Recommendations to be made to the Board in connection with the status of scientific personnel.
8. *Task Committees on Plant Production and Civilian Light Control.* These Task Committees to be recommended following recommending action by the committee.

Delinquent Members

The General Secretary reported to the committee that in line with previous action, members delinquent in their dues payment were being dropped from the mailing list in February 1951, and would not receive the February issue of the publication.

Miami To Be Host to Southern Regional Conference

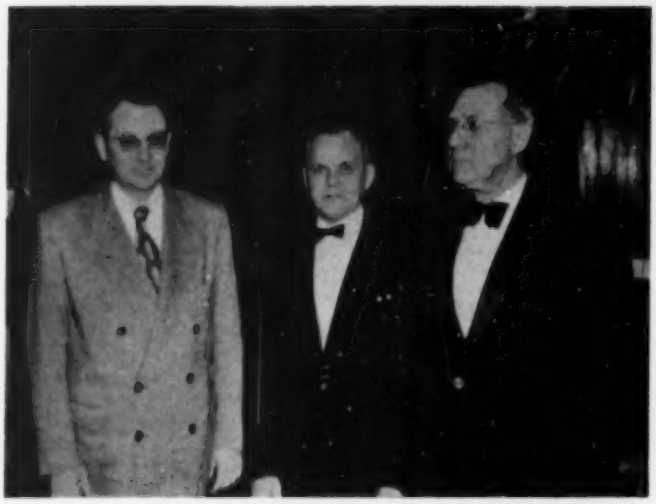
Advance program of the Southern Regional Conference indicates that a particularly worth while meeting is scheduled, for a particularly popular spot — Miami Beach, April 9 and 10. A. C. Bergh, Chairman of the Conference Program and Papers Committee, has announced details of the five sessions scheduled, listing some fourteen leading speakers. Some of the subjects scheduled will be: Use of aluminum alloys for standards; outdoor lighting; thermoset plastics in lighting; lighting practice with lens forms; lighting for merchandising; downlighting for commercial interiors; use of recessed troffers, and color correction and other improvements in mercury lighting.

Guest of honor at the Conference will be I.E.S. President, Walter Sturrock, who is scheduled to address the opening session.

Conference headquarters will be the Atlantis Hotel in Miami Beach.

Regional Conferences for 1951

March 4-6	Southwestern Region	Corpus Christi, Texas
March 22-24	Pacific Northwest Region	Spokane, Washington
April 9-10	Southern Region	Miami Beach, Florida
May 9-11	Canadian Region	Quebec, Quebec
May 14	Midwest Region	Des Moines, Iowa
May 24-25	Great Lakes Region	Cincinnati, Ohio



NEW ENGLAND SECTION and National Officers at the annual President's Night meeting held in Boston January 10. Left to right: Charles H. Goddard, past-president of I.E.S., President Walter Sturrock, and John Young, Chairman of the New England Section.

President Sturrock Urges Cooperation in Defense Program

Speaking at the annual President's Night Dinner, held January 10 at the Hotel Puritan, Boston, by the New England Section, I.E.S., President Walter Sturrock urged the cooperation of the entire I.E.S. membership in the nation's defense program.

Mr. Sturrock's key address in New England outlined ways in which the lighting engineer, electrical contractor and others associated with the lighting industry will soon be called upon to participate in the country's defense measures. Local organization at Section and Chapter level was especially urged, together with expansion of I.E.S. service to community and civic organizations.

Mr. Sturrock is at present on an extensive trip throughout the country during which he is attending Regional Conferences and addressing I.E.S. members in many of the Sections and Chapters along his route. Important discussions are also expected to be held with local officers and boards of managers on ways in which the Society may best serve the country on the local level.

Editor Appointed for Illuminating Engineering

The Society's General Secretary, A. H. Manwaring, has announced the appointment of Miss Ruby Redford as Editor of ILLUMINATING ENGINEERING, acting on the recommendation of the Publications Committee. Since August 1950, Miss Redford has been serving as Acting Editor, following the resignation of G. Ross Henninger.

Miss Redford joined the headquarters staff in 1942 as Office Editor, in which capacity she edited and produced ILLUMINATING ENGINEERING in its "Transactions" format. With the expansion of the journal in January 1949, she was appointed Production Editor of the new magazine.

Prior to her association with the publications staff at I.E.S. headquarters, Miss Redford was with the General Electric Co. Engineering Division, Nela Park, Cleveland, Ohio, joining that firm in 1930.

Ruby Redford

A full member of I.E.S. since 1946, Miss Redford has for many years been active in the Society's work, prior to and since her association with the headquarters staff. For a number of years she was Secretary of the national Publications Committee, and has served as officer and member of the executive boards of both the Cleveland Section and New York Section Residence Lighting Forums. Miss Redford was educated at the Riverdale Collegiate Institute, Toronto, Canada, Western Reserve University, Cleveland, Ohio, and Columbia University, New York City.

Industrial Bulletin Available To I.E.S. Members

"Planned Lighting for Industry" is the title of a new 40-page bulletin prepared by the Engineering Division of General Electric Lamp Department. This bulletin (LD-4) is just off the press. Engineers and production executives with problems of plant and worker efficiency under emergency conditions will find in the bulletin many ideas on lighting which offer valuable, relevant information.

Free copies are available for I.E.S. members by writing General Electric, 166-IE, Nela Park, Cleveland 12, Ohio.

Army Engineering Research Program Stepped Up

Civilian position vacancies for more than 300 engineers and other technical personnel at the Army Engineer Research and Development Laboratories have been created by the stepped-up national defense program, Colonel O. B. Beasley, Commanding Officer of the Laboratories, has announced.

An immediate need exists for mechanical, civil, electrical, electronic, chemical and photogrammetric engineers, technical writers and architects. Also included in the vacancies are draftsmen, surveying and cartographic engineers, technical and engineering aides (sub-professional). Applicants should write to Commanding Officer, Engineer Research and Development Laboratories, Fort Belvoir, Va.

Lighting Design Report

The report of the Committee on Lighting Design Practice, "Uniform Methods of Presentation and Calculation of Room Indexes, Coefficients of Utilization and Maintenance Factors," will be available in multilith form from I.E.S. headquarters. Orders sent before May 1 should be addressed to 51 Madison Avenue, New York 10, N. Y. After May 1, the address should be 1860 Broadway, New York 23, N. Y.

(*Continued on page* 10A)

The Nation's Capital INVITES YOU . . .

TO ATTEND THE **I.E.S.**

NATIONAL TECHNICAL CONFERENCE

Aug. 27–30, 1951

THE CAPITOL

CONFERENCE HEADQUARTERS

Plan Now!

- A GREAT I. E. S. CONFERENCE AWAITS YOU
- TIMELY PAPERS AND DISCUSSIONS
- LIGHTING OF FAMOUS BUILDINGS
- TOURS TO HISTORICAL SHRINES
- EDUCATION — INSPIRING TO YOUNG AND OLD
- COOL — COMFORTABLE RESORT ATMOSPHERE
- ENTERTAINMENT AND RELAXATION

The SHOREHAM HOTEL

Gateway to COOL and BEAUTIFUL Rock Creek Park

TEN MINUTES TO DOWNTOWN WASHINGTON

ONE OF THE WORLD'S FINE HOTELS

IT SEEMS TO ME

Is Compromise Necessary?

To the Editor:

In a recent issue of I. E.* there were two letters which seem to me to emphasize the opposition we have within our ranks to the discharge of our obligation to society as a technical, non-commercial organization.

In one letter, a fixture manufacturer holds forth against the adoption of the basic idea of comfortable seeing conditions (*i.e.*, low brightness ratios) because such a rule (found in the "Q. and Q. Committee Report No. 1") "penalizes present-day practice and pocketbooks." If lighting practice had been concerned solely with such considerations in the past it is pretty obvious that lighting practice would not be where it is to-day.

It seems to me that the idea that lighting progress should be hamstrung because it comes hard on some or all of us is most short-sighted.

I also am inclined to take exception to the general thesis that the only way to get a good lighting photograph is to use supplementary lighting or to re-touch the photograph. I have personally taken many photographs of office and school lighting installations, or stood by the side of the photographer when they were taken, which photographs were not made with any "photographic" illumination and which were printed without any retouching. It has been my experience that if such a lighting installation is well enough lighted to be worthy of a photograph there will be enough light to register and brightness ratios will not be so bad that the photograph will be "spoiled."

It seems to me that I have observed a great many more photographs which have given a misleading impression as to the visual effect of the photographed installation because of the use of supplementary lighting, than I have observed photographs taken without supplementary lighting which depicted the visual effect as materially worse than it actually was. — WILLIAM G. DARLEY, *Darley and Moses, Consulting Engineers, Austin, Texas.*

*January ILLUMINATING ENGINEERING, pp. 10A and 13A.

Plastic Ceilings

To the Editor:

In the January 1951 issue of ILLUMINATING ENGINEERING there appeared two articles dealing with plastic ceilings.

The first article on pages 26-28 by Spencer shows a plastic ceiling in a small (20′ x 20′) machine shop at Brown University having a coefficient of utilization of 0.687, a maintenance factor of 0.87 and a first cost of $1.76 per sq. ft.

On page 39 of the same issue is a description by Brainerd of a plastic ceiling in a control room at Barbadoes Generating Station of Philadelphia Electric Company. The room is 30′ x 72′ (ceiling height 16′). The utilization factor is 0.225; the depreciation factor (as measured by Tuck) is (15/36) 0.42 and the first cost as given by Brainerd is $10 per sq. ft.

As a check on the Brainerd article, a recent store installation has an area of 11′6″ x 55′ (ceiling height 13′9″) and has a utilization factor of 0.200. No data are available on depreciation factor and cost. Transparent ceilings with lights above are not new as about twenty-five years ago this was a favorite method of lighting sports arenas (of which the Milwaukee Auditorium was typical), and generating station control rooms (of which Conowingo was typical). Data on many of these jobs were secured and the outstanding faults of such constructions were an inherent low utilization efficiency of about 10% (for ceiling height of 30′), high depreciation due to dust and dirt collecting on the upper glass surface (an average of 0.50) and high first cost.

I cannot agree with Spencer's inference in her first paragraph that correct footcandles is secondary to quality in lighting industrial plants. Any modern industrial lighting installation has *some* quality and correct footcandles is a must, and any money left over can be put into additional quality. A good comparison would be a Chevrolet versus a Cadillac. They will both get you there in about the same time (keeping in mind the practical considerations of speed laws). No one will question the fact that the driver will be less tired in the Cadillac. Not everyone, however, can afford the added increment of comfort afforded by the Cadillac.

I seriously question Spencer's figures on utilization, depreciation, and cost of plastic-all ceiling as my own experience would indicate that her utilization factor is about three times too high, that her depreciation factor about two times too high and that her cost figure is about one-fifth the proper value. — DAVID H. TUCK, *Holophane Company, Inc., New York, N. Y.*

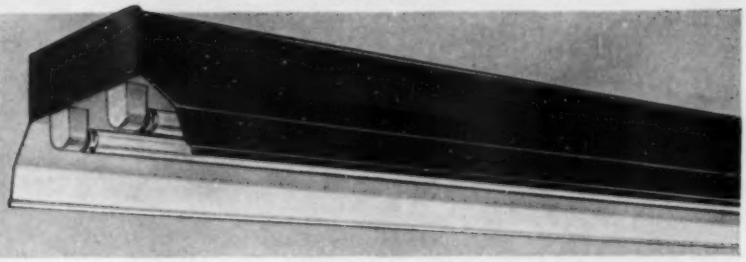
(New Member Listing on page 14A)

Installations to See When You Visit Detroit

Installation	Address	Interesting Feature
United Savings Bank	1122 Griswold	Indirect lighting, center luminaire has 28 300W lamps
Harry Suffrin (new addition)	Shelby and State	Luminaires plus adjustable spots for highlighting
Clayton's (2nd floor)	Michigan and Shelby	Louvered — four T-12 Slimline lamps on supporting channel
People's Outfitting Co. (4th floor)	Michigan and Shelby	Louvered section, with T-12 Slimline lamps, made by display department of store
B. Siegel Co.	W. 7 Mile and Steepel	Recessed troffers with Slimline T-8 lamps, recessed adjustable PAR spots
Abstract and Title Guaranty Co.	735 Griswold	Continuous row of Slimline T-12 lamps louvered on supporting channel
Lawyers Title	607 Griswold	Two panelux luminaires with T-8 slimline lamps suspended by two hangers on supporting channel
City Bank mural (2nd floor)	Penobscot Bldg.	Special incandescent luminaire made to wash mural with light from both sides of room
American Assoc. Insurance Co.	Guardian Bldg. (11th floor)	Continuous row of two 40W fluorescent louvered luminaires
Detroit Fire and Marine Insurance	615 Shelby	Slimline T-12 lamps in louvered unit on supporting channel
Detroit Bank Bldg.	State at Griswold	Entire building relighted using glass bottom two 40W fluorescents
Detroit Bank	W. 7 Mile and Livernois	Continuous row two 40W fluorescent glass bottom in general area and four 40W over tellers' and work area
Detroit Bank	W. Gd. Blvd. and 12th	Same as above except luminaires are recessed and spaced rather than in a continuous row

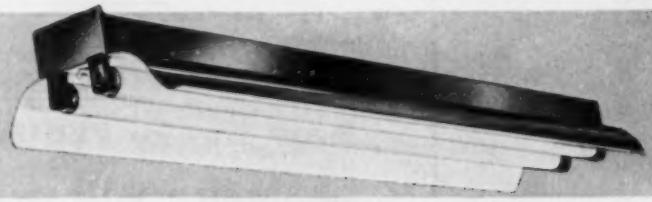
more and more

wow! top value! Model No. 2118—latest MITCHELL 8-foot 2-lamp Slimline industrial unit—the low-cost, high-efficiency fixture of a thousand uses. Features: Stroboscopically corrected, Instant-Start, 1-piece 8-foot channel, 2-piece reflector, push-type lampholders . . . U/L approved, union-made and guaranteed.



the dollars are in industrial lighting

full size! low cost! Model No. 2019—top value in super-efficient industrial lighting. Uses 2-T-12 40-watt lamps. Features: 13" wide reflector, 5" Hi-Efficiency lamp spacing, heavy all-steel construction . . . U/L approved, union-made. Ideal for low-cost lighting over assembly lines.



more and more

unbeatable buy! Model No. 2018—rugged, dependable 2-40 watt industrial unit designed for smooth, high-intensity lighting in plants and shops. Heavy all-steel construction, easy versatile mounting, advanced-design reflector. Lowest cost quality industrial on the market.

the dollars are in MITCHELL!

You don't have to be an expert to know where the lighting dollars are going today. And the men who know industrial lighting can tell you *from long experience* that the way to make those dollars is to sell the MITCHELL Line. Here's why: 1. You have a *full line* of models to fill *all* industrial needs—and *each* model is a volume seller. 2. You have *quality*—the top lighting efficiency and exclusive operating and maintenance features that have made MITCHELL the preferred name in industrial lighting. 3. You sell a prestige product—E.T.L. and R.L.M. certified—U/L approved—union-made—guaranteed for one full year. 4. You have a selling edge—because MITCHELL quality, geared to big volume production, costs less and sells for less.

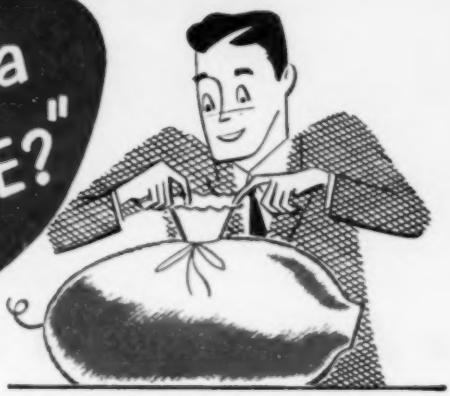
Insure your position in the industrial lighting market now—write today for full information on the dollar-making complete MITCHELL Industrial Lighting Line.

Mitchell Manufacturing Company
2525 North Clybourn Avenue • Chicago 14, Illinois
In Canada: Mitchell Mfg. Co., Ltd., 11-25 Davies Ave., Toronto

MITCHELL
Specified Most by Men Who Know

Get your share of the dollars in today's biggest market. Write for detailed descriptions and full specifications covering MITCHELL Industrial Lighting Units.

Why gamble on a "PIG IN A POKE?"



you know Exactly how every FLEUR·O·LIER luminaire will perform

There's no guessing about how a Fleur-O-Lier lighting installation will perform. You know in advance the tested, certified illuminating performance.

This certainty of results is possible because for every Fleur-O-Lier fixture there is available complete, authoritative performance data. Thus, you get the precise lighting results specified by the architect, contractor or lighting advisor.

Fleur-O-Lier gives you these advantages:

1. The Fleur-O-Lier Index System Rating, assigned by Electrical Testing Laboratories, Inc., after careful test, tells exactly what the illuminating characteristics of the luminaire are.

2. Complete photometric data is compiled by ETL.

3. Coefficients of utilization are computed by ETL. This data is essential in selecting the most suitable fixtures for the installation.

4. Certification by ETL assures the fixture was made to the rigid specifications covering electrical and mechanical features.

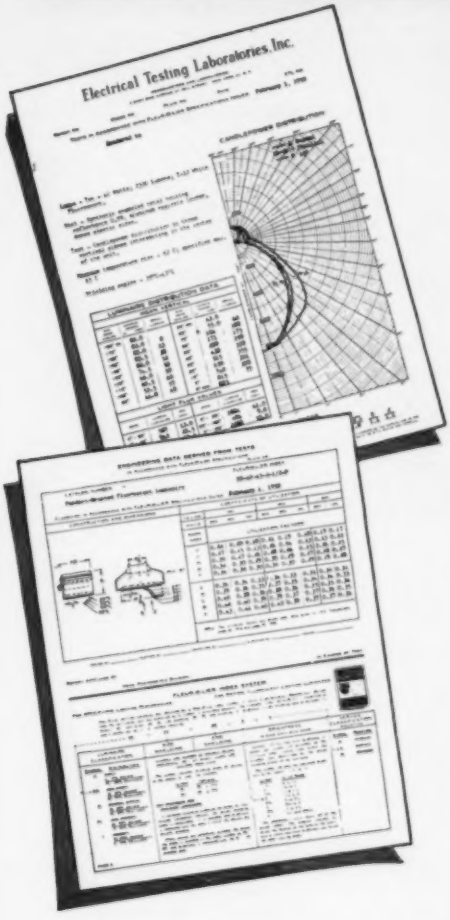
All this essential information lets you know in advance just what you're getting when you specify Fleur-O-Lier.

FLEUR·O·LIER

Manufacturers

2116 Keith Building · **Cleveland 15, Ohio**

Fleur-O-Lier is not the name of an individual manufacturer, but of a group of fixtures made by leading manufacturers. Participation in the Fleur-O-Lier program is open to any manufacturer who complies with Fleur-O-Lier requirements.



FLEUR-O-LIER DATA SHEETS give complete information

Manufacturers of Fleur-O-Lier fixtures provide Standard Data Sheets which give complete and detailed information on each Fleur-O-Lier fixture. Here, brought together on one sheet, is everything you need to know about the fixture — shielding — brightness — light distribution data — utilization factors — and construction and dimension details.

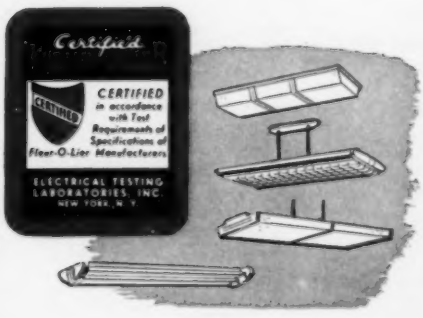
With more than 300 Fleur-O-Lier fixtures available from 25 different manufacturers — you have a wide selection of units to meet the needs of any installation.

How the Fleur-O-Lier System Enables You to Specify and Select the Right Units

The Fleur-O-Lier Index System makes the specification and selection of lighting fixtures extremely simple. Merely ask the specification writer to express the desired illumination characteristics in the simple formulas of the Fleur-O-Lier Index System.

Then the selection of lighting equipment that fits exactly the requirements of the installation is easy. Choose from fixtures that have the requested Fleur-O-Lier Index System formula and you know you'll get the desired lighting results.

Don't take chances . . . specify Fleur-O-Lier and *know* what you're getting!


Certified
CERTIFIED
in accordance with Test Requirements of Specifications of Fleur-O-Lier Manufacturers
ELECTRICAL TESTING LABORATORIES, INC.
NEW YORK, N. Y.

Free Booklet

Write for your free copy of the new booklet giving complete details of the Fleur-O-Lier Index System.

Ask also for Electrical Testing Laboratories' report on performance ratings assigned to the 300 Fleur-O-Lier fixtures.

NEW MEMBERS

At the meeting of the Council Executive Committee held in New York City, February 8, 1951, the following were elected to membership:

Alamo Chapter

Associate Member:

Goodman, W. R., Southern Electric Supply Co., San Antonio, Tex.

British Columbia Section

Associate Members:

Carlson, S. G., Electrical Service League of B. C., Nanaimo, B. C.

Lindgaard, Harold, C. H. E. Williams Co., Ltd., Vancouver, B. C.

Capital Section

Member Emeritus:

Crittenden, E. C., 1715 Lanier Place, N. W., Washington, D. C.

Chicago Section

Member:

Kurtzon, Albert, ALKO Mfg. Co., Chicago, Ill.

Associate Members:

Amstutz, R. H., R. R. Donnelly & Sons Co., Chicago, Ill.

Cuonzo, G. E., Commonwealth Edison Co., Chicago, Ill.

Hafner, E. W., Commonwealth Edison Co., Chicago, Ill.

Heeren, H. B., Heeren Electric Co., Kankakee, Ill.

Johnson, H. W., Commonwealth Edison Co., Chicago, Ill.

Maloney, J. C., Electric Supply Co., Chicago, Ill.

Murphy, R. T., Public Service Co. of Northern Ill., Northbrook, Ill.

Nordquist, R. G., Luminator, Inc., Chicago, Ill.

Perry, F. W., Commonwealth Edison Co., Chicago, Ill.

Scheuerman, J. F., Commonwealth Edison Co., Chicago, Ill.

Urbanik, E. J., Chicago Park Dist., Electric Section, Chicago, Ill.

Wotruba, G. W., Commonwealth Edison Co., Chicago, Ill.

Student Member:

Jacobek, G. L., University of Illinois, Urbana, Ill.

Cleveland Section

Associate Member:

Thomason, H. C., Westinghouse Electric Corp., Cleveland, Ohio

Student Member:

Geisheimer, Fred, Case Institute of Technology, Cleveland, Ohio

Connecticut Section

Member Emeritus:

Simpson, B. E., 97 South Main St., West Hartford, Conn.

Associate Members:

Booth, W. L., Connecticut Light & Power Co., Danielson, Conn.

Clifford, P. W., Hubbard, Lawless & Blakeley, New Haven, Conn.

Hartstein, Arnold, Ruby-Philite Corp., Long Island City, N. Y.

Michaud, C. J., Jr., General Electric Co., Bridgeport, Conn.

Florida Chapter

Associate Members:

Bedford, R. C., Florida Power Corp., St. Petersburg, Fla.

Griffin, J. D., Southeast Joslyn Co., Jacksonville, Fla.

Ingram, Esther M., 204 Professional Bldg., Winter Haven, Fla.

Foreign Non-Section

Member:

Makower, G., International General Electric Co., Inc., New York, N. Y.

Associate Members:

James, K. G., Singapore Municipality Electricity Dept., Singapore, Malaya

Prieto Urioste, Carlos, Libertad #38, Santiago de Chile, Chile

Georgia Section

Members:

Parker, W. D., Alabama Power Co., Montgomery, Ala.

Springer, D. A., 22 E. 12th St., Anniston, Ala.

Associate Member:

Edwards, M. L., Ender Mfg. Co., Atlanta, Ga.

Heart of America Section

Associate Member:

Williams, V. N., Mid-West Chandelier Co., North Kansas City, Mo.

Indiana Chapter

Associate Member:

Ransford, G. E., Indianapolis Power & Light Co., Indianapolis, Ind.

Student Members:

Davis, A. R., Purdue University, W. Lafayette, Ind.

Solomon, A. H., Purdue University, W. Lafayette, Ind.

Inland Empire Chapter

Associate Members:

Cooper, R. B., Columbia Electric & Mfg. Co., Spokane, Wash.

LeVon, Mihran, Jr., Philco Corp., Moses Lake, Wash.

Wilkinson, R. L., National Electrical Contractors Assoc., Spokane, Wash.

Iowa Section

Associate Members:

Anderson, P. D., Iowa Southern Utilities Co., Centerville, Ia.

Rucks, H. E., Interstate Power Co., Dubuque, Ia.

Michigan Section

Member:

Stiner, K. P., City of Detroit—Electrical Inspection Bureau, Detroit, Mich.

Mississippi Chapter

Associate Members:

Brock, T. B., General Electric Co., Jackson, Miss.

Cortright, C. B., Cabell Electric Co., Jackson, Miss.

Student Members:

Anderson, T. O., Mississippi State College, State College, Miss.

Moore, W. N., Mississippi State College, State College, Miss.

Montreal Section

Associate Member:

Demers, A. H., 261 Queen St., Montreal, Que.

New England Section

Member:

Curwen, E. C., Sylvania Electric Products, Inc., Salem, Mass.

Associate Members:

Brown, W. C., Boston Edison Co., Boston, Mass.

Tice, W. C., General Electric Co., W. Lynn, Mass.

Wheeler, R. F., Graybar Electric Co., Boston, Mass.

Wilson, R. W., General Electric Co., Boston, Mass.

New Orleans Section

Associate Member:

Bentley, J. S., Jr., Westinghouse Electric Corp., New Orleans, La.

New York Section

Member:

MacDougall, John, General Electric Co., Newark, N. J.

Associate Members:

Eserky, Seymour, Electra Supply Co., Inc., Poughkeepsie, N. Y.

Falk, Norman, Holophane Co., New York, N. Y.

Sharpe, G. C., D. Eichwald & Co., Inc., New York, N. Y.

Student Members:

Jacobs, Marvin, City College of New York

Giordano, Paul, City College of New York

Northern California Section

Associate Member:

Ciampi, T. V., California Electric Supply Co., San Francisco, Calif.

Student Member:

Okamoto, Masato, University of Calif., Berkeley, Calif.

Ohio Valley Section

Member:

Alpern, Mathew, Ohio State University, Columbus, Ohio

Philadelphia Section

Associate Members:

Alexander, J. W., Electro Mfg. Co., Philadelphia, Pa.

Black, D. N., Cynwyd Electric Co., Bala Cynwyd, Pa.

Green, J. A., Fidelity-Philadelphia Trust Bldg., Philadelphia, Pa.

Ramsey, Logan, Spring Garden Institute, Philadelphia, Pa.

Pittsburgh Section

Associate Members:

Bright, Graham, Mine Safety Appliances Co., Pittsburgh, Pa.

Doherty, W. J., General Electric Co., Pittsburgh, Pa.

Hartman, J. W., Westinghouse Electric Supply, Pittsburgh 12, Pa.

Hornickel, J. C., General Electric Co., Pittsburgh, Pa.

Kingsbury, H. F., Pittsburgh Corning Corp., Port Allegany, Pa.

Kunkle, J. P., General Electric Co., Pittsburgh, Pa.

Rochester Chapter

Associate Members:

Clawson, J. W., Rochester Gas & Electric Corp., Canandaigua, N. Y.

Pittman, M. D., Rochester Gas & Electric Corp., Sodus, N. Y.

Schroeder, Willard, Rochester Gas & Electric Corp., Fillmore, N. Y.

Rocky Mountain Section

Associate Member:

Larsen, H. R., L & L Electric Contracting & Engineering Co., Denver, Colo.

(Continued on page 33A)

Drafting Room • J. H. Holan Corporation • Cleveland, Ohio

Lighting a Drafting Room

to give visual comfort for increased efficiency

with the Wakefield GRENADIER

"We have found this lighting arrangement is very satisfactory and agreeable to the workers —as there are very few shadows on the drawing boards—which is an aid to visual comfort and efficiency." So reports Herman J. Troche, vice president of the J. H. Holan Corporation, Cleveland, Ohio.

The Wakefield fluorescent Grenadier is not only an efficient lighting tool—it's a *complete family* of efficient lighting tools. Consider the matching possibilities in the following:

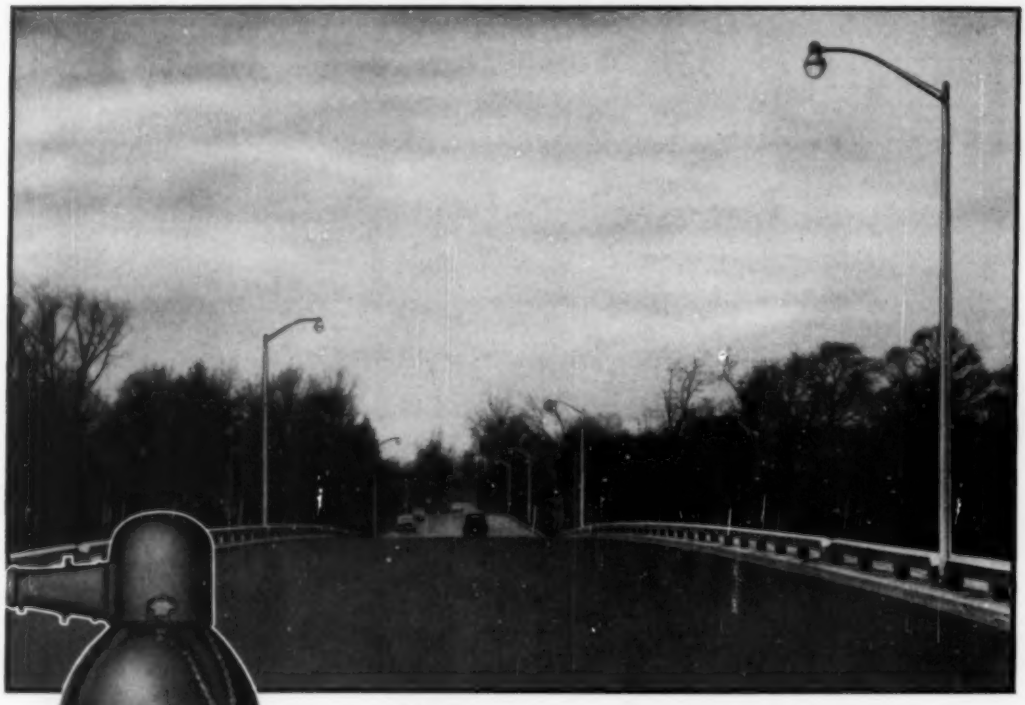
1. Available for either two or four bi-pin lamps.
2. Available for either two or four slimline lamps.
3. Available for continuous runs or in single 4 foot units.
4. Available for suspension, canopy or on-ceiling mounting.
5. Available with single or double movable spotlights set in line or at corners.

The Grenadier is a solidly built, well shielded, louvered fixture with metal-framed translucent plastic side panels. It is easy to install (a one-man job) and easy to maintain; all reflecting surfaces are turned downward and do not readily collect dust. A booklet describing and illustrating the Wakefield Grenadier Family is available. Write to The F. W. Wakefield Brass Company, Vermilion, Ohio.

Wakefield Over-ALL Lighting

FOR SCHOOLS, OFFICES, DRAFTING ROOMS, STORES

Pemco LIGHTING GOES HAND IN HAND WITH MODERN CONSTRUCTION



PEMCO 81354114 Modern Alzak Luminaires (mounting staggered) were specified for the Walnut Lane Bridge. PEMCO Luminaires are available in a variety of types and mountings to meet any local condition or requirement.

Check your "Lighting Information File". If you do not have PEMCO General Catalog No. 90 be sure to request your copy today.

Pemco LUMINAIRES LIGHT FIRST PRESTRESSED CONCRETE BRIDGE IN UNITED STATES

The Walnut Lane Bridge across Paper Mill Creek Valley in historic Fairmount Park, Philadelphia, is the first prestressed bridge to be built in the United States. The main girders, each weighing approximately 150 tons, were precast to one side of the bridge location and lifted into position 50 feet above the floor of the valley. In undertaking a modern prestressed concrete bridge Philadelphia has made an admirable contribution to American engineering. PEMCO is proud of the distinction of having had its Luminaires chosen to light this miracle in concrete.

There are PEMCO Luminaires, Poles and Brackets to meet the most exacting requirements of modern engineering. Let us study your problem and recommend the PEMCO Lighting Equipment best suited for your job.

PHILADELPHIA ELECTRICAL & MANUFACTURING CO.
1200-36 N. 31st Street, Philadelphia 21, Pa.
Sales Offices in Principal Cities

COMMITTEES

COMMITTEES 1950-1951

Except as noted below, all committees are appointed by the President, subject to approval of the Council, and terminate at the time of the first Council meeting each new administration, in the month of October. The duties of each committee are indicated.
Walter Sturrock, President, ex-officio member of all committees.

STANDING COMMITTEES

BOARD OF FELLOWS — To evaluate the eligibility of candidates for transfer to the grade of Fellow and recommend their election by Council.
H. M. Sharp, Chairman, 82 Smallwood Drive, Snyder 21, N. Y.
Paul H. Goodell — H. H. Magdsick
Ward Harrison — G. F. Mudgett
J. L. Stair

COUNCIL EXECUTIVE — To conduct the affairs of the Society between Council meetings.
Walter Sturrock, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio
R. F. Hartenstein — A. H. Manwaring
S. G. Hibben — E. M. Strong

FINANCE — Direct supervision of the financial affairs of the Society, present annual report on its financial condition and make recommendations to Council as to investments of money and upon all specific appropriations.
M. N. Waterman, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.
R. F. Hartenstein — C. C. Keller
G. J. Taylor

GENERAL BOARD OF EXAMINERS — Evaluate the eligibility of applicants for admission to membership or transfer to the grade of Member and submit to Council their nominees for election to the grade of Member Emeritus.
E. M. Fahey, Chairman, Public Service Electric & Gas Co., 80 Park Place, Newark 1, N. J.
Caroline E. Horn — T. O. Jorgensen

MEDAL AWARD — To consider qualifications of candidates for I.E.S. Medal; submit recommendations to Council and prepare citation for the award.
G. W. Beals, Chairman, The Miller Company, Meriden, Conn.
W. C. Brown — R. W. Staud
C. H. Goddard — L. E. Tayler
M. Luckiesh — J. S. Walsh
J. L. Stair — Howard Wright

PAPERS — To procure, review and approve all technical papers and discussions thereof, for presentation before National Conferences of the Society.
Hoyt P. Steele, Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.
H. W. Horn, Vice-Chairman, University of Illinois, 201 E. E. Annex, Urbana, Ill.
R. D. Bradley — K. M. Reid
P. H. Hildebrand — H. L. Wright
Caroline E. Horn — R. R. Wylie
R. W. McKinley — R. M. Zabel

PUBLICATIONS — To be responsible for the procurement, review and approval of all material for the publications of the Society other than technical papers approved by the Papers Committee for presentation at National Conferences of the Society and their discussions, and committee reports, for which it will have publication responsibility only. Shall also be responsible for the editing, printing and business management of the publications of the Society.
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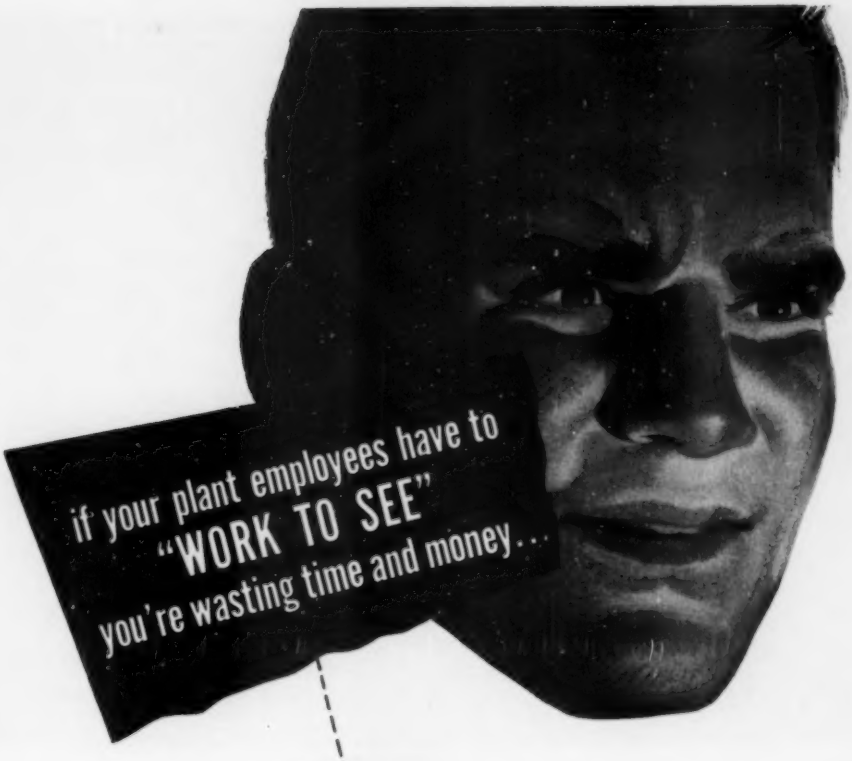

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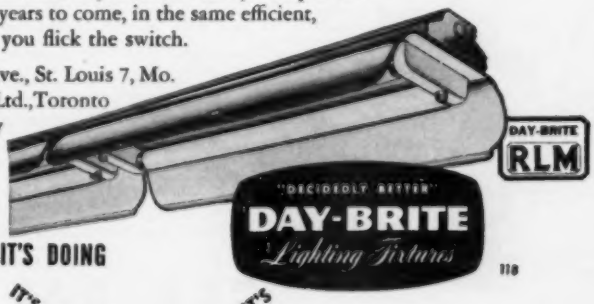

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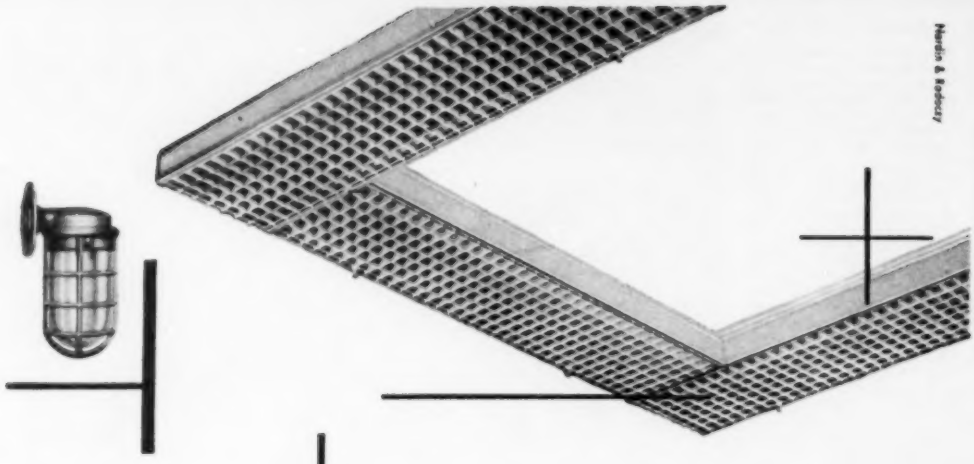

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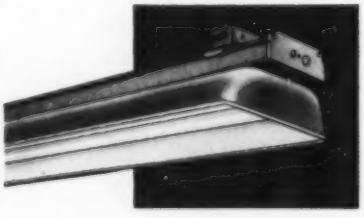

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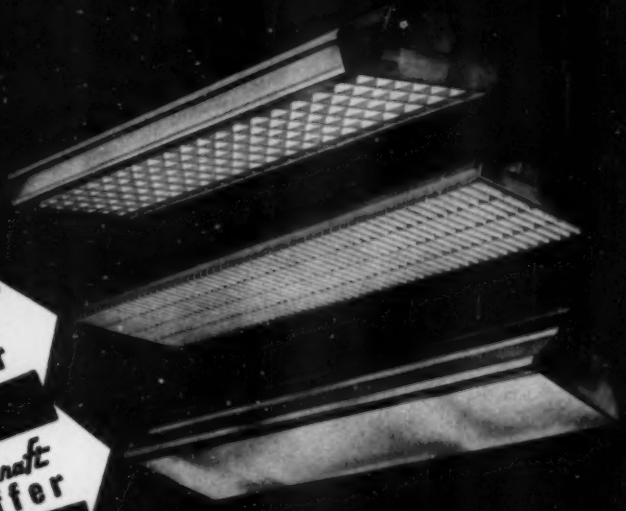
Continued on page 28A

the light side of the office

Smithcraft mercury

Smithcraft director

Smithcraft troffer



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Continued from page 26A

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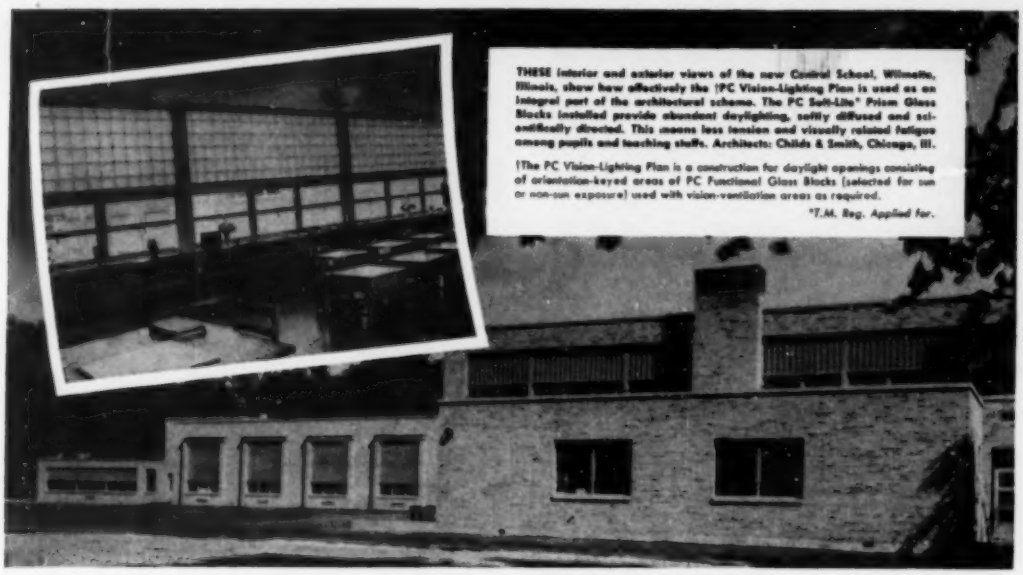

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Make your lighting plan complete ...with PC Functional Glass Blocks

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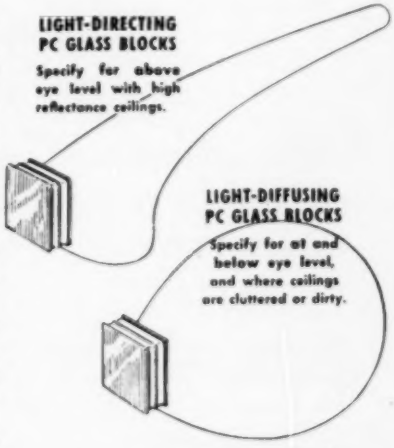
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6 REASONS why architects, contractors, business executives specify LEADER Industrial Fluorescent Fixtures

What are they?

● A unit for every lighting job! ● Easy servicing! ● Versatility in mounting! ● Flexibility of installation! ● Precision construction! ● Finest quality materials used throughout!

In addition, Leader brings you an unusually wide variety of 40-watt, 100-watt or Slimline units, available in lengths from 48" to 96", with sturdily constructed, accessible channels. Leader also features such refinements as removable reflectors with captive latch, time-saving turret-type sockets with spring-pressure grip, easy yet rigid end-to-end coupling for optional continuous run installations.

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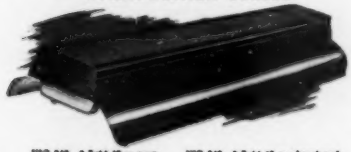
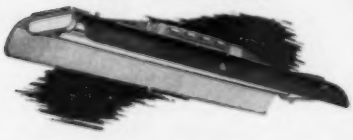


100-248—2-light 48-w. open
100-348—3-light 48-w. open
100-2-196—2-light 100-w. open
100P-248—2-light 48-w. closed end
100P-348—3-light 48-w. closed end
100P-2-196—2-light 100-w. closed end

Durable and strongly built fixtures, neat in appearance. All-steel housing, channel and reflectors. On continuous run wireway installations 2-light sections may be grouped with 3-light or blank sections. One-piece channel for twin 40-watt sections (8' length) or 100-watt sections (10' length).

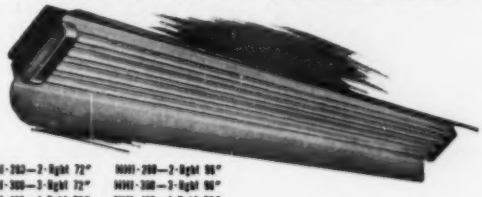
ZEPHYRLITE SERIES



200-248—2-light 48-w. open
200-348—3-light 48-w. open
200-248—2-light 48-w. closed end
200-348—3-light 48-w. closed end

Corrugation incorporates unusual strength and rigidity into units. No warping, twisting or sagging! All-steel housing, reflectors, deep drawn channel. 2-light units can be easily converted to 3-light whenever desired. For individual or continuous run wireway installation.

NEW HORIZON SLIMLINE INDUSTRIAL SERIES



NHI-283—2-light 72"
NHI-383—3-light 72"
NHI-483—4-light 72"
NHI-288—2-light 96"
NHI-388—3-light 96"
NHI-488—4-light 96"

These heavy-duty Slimline fixtures bring streamlined styling to industrial lighting and provide exceptionally high light intensity. All-steel channel and reflectors. Designed primarily for continuous run wireway installations. Instant-start operation in choice of 120, 200, 300 or 425 ma. Multi-bulb units for up to 10 lamps available on special order.

Leader

Sold and installed by better electrical dealers and contractors everywhere.

America's No. 1 Lighting Equipment Manufacturer

LEADER ELECTRIC COMPANY

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Campbell-Leader, Ltd.: Brantford, Ontario • Canada

General Electric's newest ads boost "Light-Conditioning"

RECIPE FOR MAKING A ROOM BIGGER...WITH LIGHT
How G-E "Light Conditioning" makes homes brighter, work lighter
GENERAL ELECTRIC
GENERAL ELECTRIC

MORE and more people are learning about Light-Conditioning—General Electric's new program to help people get the most out of their home lighting. They've read about it in G-E ads, heard about it on the General Electric Fred Waring TV show. More than a million copies of General Electric's Light-Conditioning booklet, "See Your Home in a New Light", have been distributed.

Now, we're telling the Light-Conditioning story again—with the ads above that will appear in four colors in Better Homes & Gardens, Ladies Home Journal and Saturday Evening Post. For full information on how you can tie in with the Light-Conditioning Program, see your nearest G-E Lamp District Office. General Electric Co., Lamp Department, Nela Park, Cleveland 12, Ohio.

Use these materials to promote Light-Conditioning in your territory. Left: Newspaper ad mats. Right: Light-Conditioning recipe booklet—gives 22 detailed recipes for every home lighting situation.

GENERAL ELECTRIC

(*Continued from page 14A*)

ST. LOUIS SECTION

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Gordon, A. P., National Chemical & Mfg. Co., Chicago, Ill.
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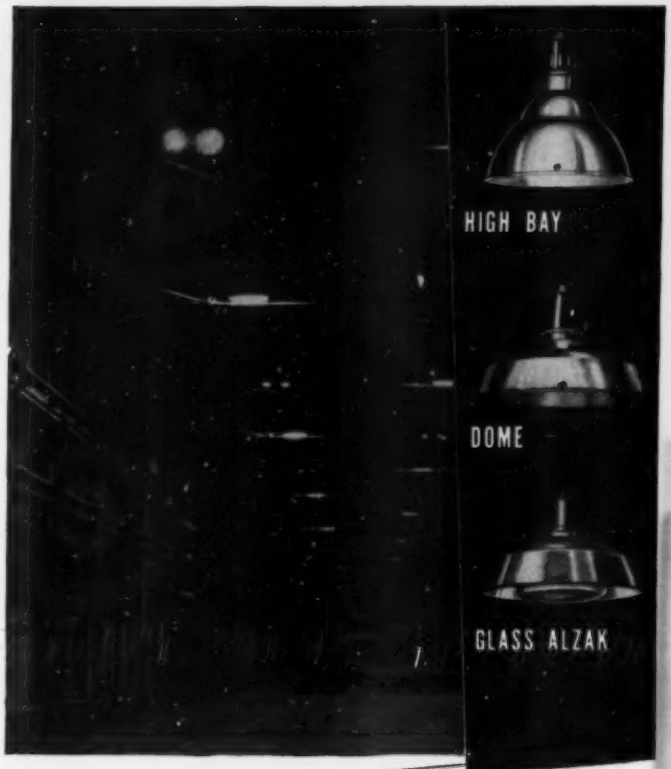
B.E.E.; Graduate, Sales for Engineers, CCNY; some lighting sales, diversified engineering and manufacturing background; studying for M.B.A. evenings; metropolitan N. Y. area; Associate Member I.E.S. Veteran, 27, married. Resume and interview upon request. Address Box 139, Publications Office, Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y.

ILLUMINATING ENGINEER AVAILABLE

Young man experienced in the design and production of luminaires and in the design of lighting layouts desires position as illuminating engineer. Electrical engineering graduate. Draft deferred. Address Box 140, Publications Office, Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y.



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A DIVISION OF CONSOLIDATED ELECTRIC LAMP CO.

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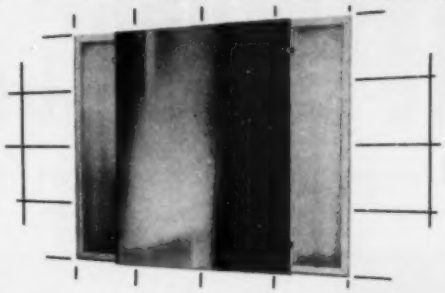
First with completely recessed lighting



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Now you can specify good lighting for the bathroom, too! The Milwaukee provides completely recessed lighting—for glareless, shadowless illumination. With *four* 20-watt fluorescent lamps, no other illumination is ordinarily needed in the bathroom. For all facts on this modern cabinet, write for Bulletin B-108. Or see your electrical wholesaler today.

CHECK THESE SPECS: Uses four 20-watt lamps, shielded with Corning Alba-Lite translucent opal glass. Trigger-start G.E. ballasts. All-welded 20-gauge cold-rolled steel. Mitered corners, filled and polished. Double-baked white lifetime enamel finish. Mirror of mirror-glazing quality polished plate glass. U/L approved. Union made. G.E. electrical equipment. 110-120 volts, 60 cycle a-c. Individually packed. Requires a wall opening of 30¾ x 24¾ x 4 in.

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The core and coil assembly of an Acme Electric Ballast is made to such a high standard of excellence that normal magnetic hum is minimized and then further silenced thru impregnation. Assembly is sealed in the case, solidly imbedded in heat and cold resisting compound. Noise free operation is assured.

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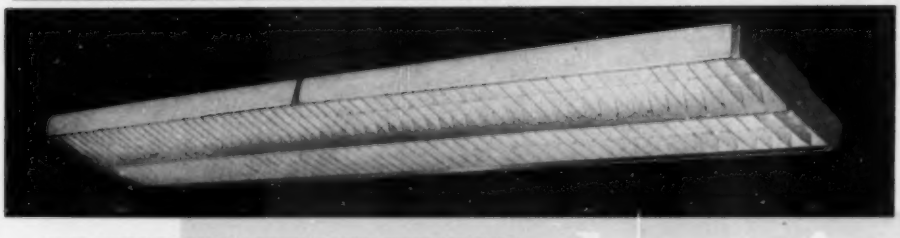

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constant light output

only SOLA Ballasts have the patented constant wattage resonant circuit

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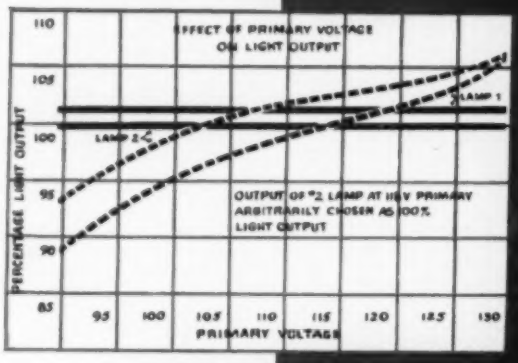
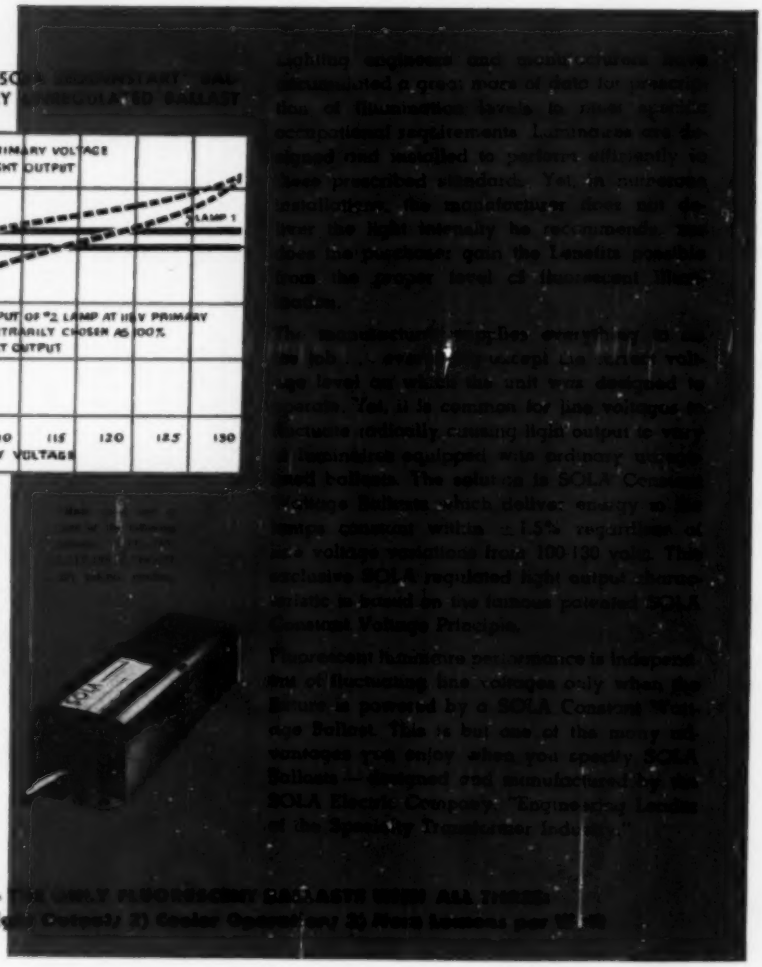


SOLA SEQUENSTART BALLAST ——

ORDINARY BALLAST - - -

A new folder listing electrical and mechanical specifications of SOLA Ballasts is available on request. Write for Bulletin C-PFL-144.



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- Full lamp life (poor ballasts may shorten lamp life by ½)
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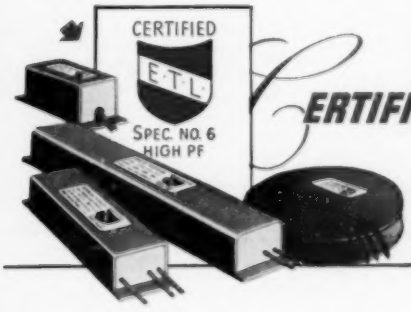
CERTIFIED BALLASTS are made to exacting specifications, then tested and checked by Electrical Testing Laboratories, Inc.

• Complete information on the types of CERTIFIED BALLASTS available from each participating manufacturer may be obtained from Electrical Testing Laboratories, Inc., East End Avenue at 79th Street, New York, New York.



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